| Revision | Approved by | Number of Pages |
|---|---|---|
| 001 | | 64 |
| **Approval Date** | 06/02-20 | |

# General Nuclear System Ltd.

UK HPR1000 GDA Project

| **Document Reference:** | **HPR/GDA/PCER/0005** |
|---|---|

**Title:**

# Pre-Construction Environmental Report

# Chapter 5

# Approach to Sampling & Monitoring

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## 5.1 List of Abbreviations and Acronyms

| | |
|---|---|
| APG | Steam Generator Blowdown System [SGBS] |
| BAT | Best Available Techniques |
| BFX | Fuel Building |
| BQF | Spent Fuel Interim Storage Facility |
| BQZ | ILW Interim Storage Facility |
| BWX | Radioactive Waste Treatment Building |
| CEX | Condensate Extraction System [CES] |
| CGN | China General Nuclear Power Corporation |
| CVI | Condenser Vacuum System [CVS] |
| DWK | Fuel Building Ventilation System [FBVS] |
| DWL | Safeguard Building Controlled Area Ventilation System [SBCAVS] |
| DWN | Nuclear Auxiliary Building Ventilation System [NABVS] |
| DWQ | Waste Treatment Building Ventilation System [WTBVS] |
| EA | Environment Agency (UK) |
| EBA | Containment Sweeping and Blowdown Ventilation System [CSBVS] |
| GDA | Generic Design Assessment |
| HEPA | High Efficiency Particulate Air |
| HLW | High Level Waste |
| HpGe | High-purity Germanium |
| HPR1000 (FCG3) | Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 |
| HVAC | Heating, Ventilation and Air Conditioning |
| ICIA | In-core Instrumentation Assembly |
| ILW | Intermediate Level Waste |
| KRT | Plant Radiation Monitoring System [PRMS] |
| LLW | Low Level Waste |

| | |
|---|---|
| MCERTS | Monitoring Certification Scheme (UK) |
| NPP | Nuclear Power Plant |
| OPEX | Operating Experience |
| P&ID | Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Design |
| PCER | Pre-Construction Environmental Report |
| PCSR | Pre-Construction Safety Report |
| PIPS | Passivated Implanted Planar Silicon |
| PIS | Particle and Iodine Sampler |
| RCCA | Rod Cluster Control Assembly |
| REA | Reactor Boron and Water Makeup System [RBWMS] |
| REN | Nuclear Sampling System [NSS] |
| REP | Radioactive Substances Regulation - Environmental Principles |
| SCCA | Stationary Core Component Assembly |
| SEL | Conventional Island Liquid Waste Discharge System [LWDS (CI)] |
| TEG | Gaseous Waste Treatment System [GWTS] |
| TEP | Coolant Storage and Treatment System [CSTS] |
| TER | Nuclear Island Liquid Waste Discharge System [NLWDS] |
| TEU | Liquid Waste Treatment System [LWTS] |
| TGN | Technical Guidance Notes |
| UK HPR1000 | UK version of the Hua-long Pressurised Reactor |

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

## 5.2 Introduction

### 5.2.1 Objective

The purpose of this chapter is to describe the approach to sampling and monitoring of final discharges and disposals of radioactive wastes. It also describes the arrangement of in-process sampling and monitoring relevant to discharges for the UK version of the Hua-long Pressurised Reactor (UK HPR1000). These arrangements described demonstrate that the design meets the requirements of item 6 of Table 1 in the *Process*

*and Information Document for Generic Assessment of Candidate Nuclear Power Plant Design (P&ID)*, Reference [1], together with the relevant principles provided in the *Radioactive Substances Regulation - Environmental Principles (REP)*, Reference [2]. This chapter is produced based on the design reference version 2.1, as described in the *UK HPR1000 Design Reference Report*, Reference [3].

### 5.2.2 Scope

This chapter covers the radioactive sampling and monitoring arrangements for the UK HPR1000, as well as techniques and systems for the measurement of radiological characteristics of radioactive waste discharged and disposal of. Information is also provided on the sampling and monitoring of the in-process radioactive wastes that whilst not discharged directly, are relevant to the wastes that are discharged.

This chapter does not cover chemical and physical related sampling and monitoring arrangements such as temperature and pressure. These are presented in relevant system design manuals and where relevant in the Pre-Construction Environmental Report (PCER) Chapter 3. Information on arrangements for gaseous and liquid in-process sampling and monitoring relevant to discharges and the final monitoring and sampling is supplemented by the content of *KRT - Plant Radiation Monitoring System Design Manual Chapter 3 System Functions and Design Bases*, Reference [4]. A demonstration that the proposals represent the Best Available Techniques (BAT) for discharges and disposals relevant radiation monitoring and sampling is conducted; using the BAT methodology described in PCER Chapter 3; and is presented in this chapter through the Claim-Argument-Evidence approach. The demonstration of BAT in this chapter (Chapter 5) focuses on the techniques proposed for monitoring and sampling arrangements. At the Generic Design Assessment (GDA) stage, it is not yet possible to provide precise details on which type of sampling and monitoring equipment will be installed for the UK HPR1000. Therefore, the focus is on techniques rather than specific equipment.

The in-process sampling and monitoring arrangements considered in this chapter include systems directly connected to the final discharge systems or structure i.e. to the Nuclear Island Liquid Waste Discharge System (TER [NLWDS]) and the Conventional Island Liquid Waste Discharge System (SEL [LWDS (CI)]) for liquid discharges and the discharge stack for gaseous discharges. The systems that feed into liquid discharge systems include the Liquid Waste Treatment System (TEU [LWTS]), the Coolant Storage and Treatment System (TEP [CSTS]), the Steam Generator Blowdown System (APG [SGBS]); and those that feed into the discharge stack include the Gaseous Waste Treatment System (TEG [GWTS]), the Condenser Vacuum System (CVI [CVS]) and radioactive ventilation systems of Heating, Ventilation and Air Conditioning (HVAC) system.

Environmental monitoring is not included within the GDA submission due to the site-specific nature of the program which needs to be developed as part of the site

specific permitting application. Monitoring during decommissioning stage is neither included since it will be designed many decades after the GDA.

The interfaces between this chapter and other chapters in the UK HPR1000 PCER are presented in T-5.2-1.

T-5.2-1 Interfaces with Other PCER Chapters

| Chapter | Interfaces Relationship |
|---|---|
| PCER Chapter 1 Introduction | PCER Chapter 1presents the summary of each PCER chapter and the P&ID route map. |
| PCER Chapter 3: Demonstration of BAT | PCER Chapter 3 Sub-chapter 3.3 presents the BAT methodology applied in the UK HPR1000 and provides the holistic BAT demonstration for the UK HPR1000. |
| PCER Chapter 4: Radioactive Waste Management Arrangements | PCER Chapter 4 presents the radioactive waste management arrangements. |
| PCER Chapter 6: Quantification of Discharges & Limits | PCER Chapter 6 Sub-chapter 6.5 presents the list of significant radionuclides and Sub-chapter 6.6 provides the estimated radioactive gaseous and liquid discharges and proposed limits to the environment. |
| PCER Chapter 8: Conventional Impact Assessment | PCER Chapter 8 Sub-chapter 8.4 presents the chemical characteristics of effluent in the TER [NLWDS] and the SEL [LWDS (CI)]. |

The description of Plant Radiation Monitoring System (KRT [PRMS]) design is presented in Sub-chapter 22.8 in *Pre-Construction Safety Report (PCSR) Chapter 22: Radiological Protection*, Reference [5]; the description of the radioactive waste treatment systems is presented in Sub-chapter 23.6, Sub-chapter 23.7 and Sub-chapter 23.8 in *PCSR Chapter 23: Radioactive Waste Management*, Reference [6]; the description of the APG [SGBS] is presented in Sub-chapter 11.3 in *PCSR Chapter 11: Steam and Power Conversion System*, Reference [7].

## 5.3 Regulatory Context

This Sub-chapter presents the regulatory requirements and forms of guidance relating to sampling and monitoring of radioactive discharges as well as in-process monitoring relevant to discharges in the UK.

### 5.3.1 P&ID Requirements

The Environment Agency (UK) (EA) has identified the information required during

the GDA stage in the P&ID. The P&ID requirements relating to sampling arrangements, techniques and systems for the measurement and assessment of the discharges and disposals of radioactive wastes are described in item 6, Table 1, as reproduced below:

***A description of the sampling arrangements, techniques and systems for measurement and assessment of discharges and disposals of radioactive waste.***

*Include:*

- *details of in-process monitoring arrangements*
- *details of arrangements for monitoring final discharges of gaseous and aqueous wastes*
- *details of arrangements for monitoring disposals of non-aqueous liquid and solid wastes*
- *a demonstration that the proposals represent the best available techniques for monitoring*
- *confirmation that the sensitivity is sufficient to:*
  - *readily demonstrate compliance with the proposed limits*
  - *meet the levels of detection specified in reference EU, 2004*

*a description of the facilities provided for independent periodic sampling (by the regulator) of final discharges of gaseous and aqueous wastes*

### 5.3.2 Relevant REP

The design of the sampling and monitoring systems shall take into account the relevant REP. The REP most relevant to sampling and monitoring are as follows:

*Principle RSMDP9 - Characterisation*

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

*Principle RSMDP13 - Monitoring and Assessment*

*The best available techniques, consistent with relevant guidance and standards, should be used to monitor and assess radioactive substances, disposals of radioactive wastes and the environment into which they are disposed.*

*Principle RSMDP14 - Record Keeping*

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

*waste disposal.*

*Principle ENDP4 - Environment Protection*

*Environment protection functions under normal and fault conditions should be identified, and it should be demonstrated that adequate environment protection measures are in place to deliver these functions.*

*Principle ENDP10 - Quantification of Discharges*

*Facilities should be designed and equipped so that best available techniques are used to quantify the gaseous and liquid radioactive discharges produced by each major source on a site.*

*Principle ENDP14 - Control and Instrumentation-Environment Protection System*

*Best available techniques should be used for the control and measurement of plant parameters and releases to the environment, and for assessing the effects of such releases in the environment.*

### 5.3.3 Other Requirements Related to Monitoring and Sampling

The codes and standards considered in PCER Chapter 5 align with UK current requirements of the applicable laws, regulations and other statutory instruments. During the GDA stage, the PCER Chapter 5 focuses on the monitoring arrangements for discharges and disposals, hence the regulations regarding equipment selection and laboratory analysis are not considered. They will be undertaken during the site-specific stage.

International standards have also been selected. Applicable codes and standards are identified in T-5.3-1.

T-5.3-1 Applicable Codes and Standards for PCER Chapter 5

| Codes and Standards | Brief Description |
|---|---|
| 2004/2/Euratom | This document provides recommendations on the standardised information on radioactive gaseous and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operations. Reference [8] and [9]. |
| BS ISO 2889: 2010 | This standard contains sets of the criteria and recommendations sample extraction, sample system design, sample transport, performance criteria and quality control for the gaseous discharges, Reference [10]. |

| Codes and Standards | Brief Description |
|---|---|
| MCERTS | Certain parts of the Monitoring Certification Scheme (UK) (MCERTS) are relevant to the nuclear industry, including the flow measure for both liquid, Reference [11], [12], and gaseous effluents, Reference [13], as well as the collection of liquid, Reference [14], and gaseous samples, Reference [15], and the analysis of aqueous samples, Reference [16]. |
| Technical Guidance Notes | Technical Guidance Notes (TGN) produced by the EA are relevant to sampling and monitoring. The main ones are M1: *Sampling Requirements for Stack Emission Monitoring*, Reference [17], M2: *Monitoring of Stack Emissions to air*, Reference [18], 245_17: *Monitoring of Radioactive Discharges to Atmosphere from Nuclear Facilities*, Reference [19] and M12: *Monitoring of Radioactive Releases to Water from Nuclear Facilities*, Reference [20]. |

## 5.4 Parameters to be Measured (Final Discharges)

### 5.4.1 Radionuclides

The 2004/2/Euratom recommends a range of radionuclides for which the discharged radioactivity needs to be assessed. The number of the nuclides (or groups of nuclides) listed in 2004/2/Euratom, is substantial. However, the guidance for limit-setting states that the number of limits set shall be kept to a minimum and ensure adequate control of the discharges and adequate monitoring of process performance, Reference [21]. Therefore, the radionuclides to be measured for the UK HPR1000 are determined based on the significant radionuclides and consider the requirements of 2004/2/Euratom and international relevant good practices.

The selection criteria and results of the significant radionuclides in the discharges are presented in PCER Chapter 6.

The list of the radionuclides in the discharges to be measured and the corresponding detection limit requirements in 2004/2/Euratom are presented in T-5.4-1 and T-5.4-2.

T-5.4-1 Radionuclides to be Measured and Detection Limit Requirement in 2004/2/Euratom (Gaseous Discharges)

| **Category** | **Radionuclides to be Measured** | **Requirement for Detection Limit ($Bq/m^3$)** |
|---|---|---|
| Noble gases | Total noble gases (Xe-133, Xe-135) | --- |
| Carbon-14 | C-14 | 1E+01 |
| Iodine | I-131 | 2E-02 |
| Tritium | H-3 | 1E+03 |
| Particulates (excluding iodine) | Co-60 | 1E-02 |
| | Cs-137 | 3E-02 |
| | Sr-90 | 2E-02 |
| | Total-alpha | 1E-02 |

T-5.4-2 Radionuclides to be Measured and Detection Limit Requirement in 2004/2/Euratom (Liquid Discharges)

| **Category** | **Radionuclides to be Measured** | **Requirement for Detection Limit ($Bq/m^3$)** |
|---|---|---|
| Tritium | H-3 | 1E+05 |
| Carbon-14 | C-14 | --- |
| Other radionuclides (excluding tritium) | Co-60 | 1E+04 |
| | Cs-137 | 1E+04 |
| | Sr-90 | 1E+03 |
| | Total-alpha | 1E+03 |

### 5.4.2 Discharge Flow

The flows of both the gaseous and liquid discharges need to be continuously and accurately measured to report the discharges of radioactive substances, using an appropriate MCERTS accredited technique if such equipment is available, Reference [12] and [13].

## 5.5 System and Equipment Design

The sampling and monitoring arrangements for the discharges are designed with the objective of providing information on the radioactivity of the discharges to demonstrate compliance with the environmental permit.

Methods and techniques of sampling and monitoring for the UK HPR1000 are described from section 5.5.1 to section 5.5.6. At this early design stage, these methods and techniques can be shown to meet the requirements of the detection limit for the radionuclides listed in 2004/2/Euratom but no specific equipment supplier is selected during the GDA. However, the sampling and monitoring equipment may be updated as the technology evolves. The accessibility and work space for sample collection, for the maintenance and calibration of the equipment are also considered.

### 5.5.1 Sampling and Monitoring Locations

The final radioactive discharge points have been identified to ensure the records of the radioactive discharges to the environment can be made. Two major discharge points have currently been identified: one for gaseous discharges and the other for liquid discharges. The overview of the gaseous effluent routes and liquid effluent routes are shown in F-5.5-1 and F-5.5-2 respectively.

a) Gaseous discharges

As shown in F-5.5-1, the gaseous radioactive effluents are collected and treated by three systems: the TEG [GWTS], HVAC system, and the CVI [CVS]. Among them, HVAC system consists of several ventilation subsystems and in this document only the radioactive ventilation systems that operate under normal condition are within the scope. These include the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), the Fuel Building Ventilation System (DWK [FBVS]), the Waste Treatment Building Ventilation System (DWQ [WTBVS]), the Safeguard Building Controlled Area Ventilation System (DWL [SBCAVS]) and the Containment Sweeping and Blowdown Ventilation System (EBA [CSBVS]). After relevant treatment, the gaseous effluents are discharged by the HVAC systems via the discharge stack, which is located on the top of the Fuel Building (BFX).

The sampling points for final gaseous discharges are in the discharge stack, downstream of any abatement systems, at position where the effluents are well mixed (criteria are given in section 6.2 in Reference [10]) and far away from any disturbance. The monitors and samplers, which collect and measure the particulate material, iodine and noble gases, are located in an easily accessible room where the dose rate is low.

The in-process sampling and monitoring points for the gaseous effluents generated in the different systems are presented in F-5.5-4.

b) Liquid discharges

F-5.5-2 shows the overview of the liquid effluent routes. As shown in this figure, the liquid radioactive wastes are discharged by two systems: the TER [NLWDS] and the SEL [LWDS (CI)]. These two systems are connected to one common final discharge line. The liquid radioactive waste is discharged to the environment via the system outfall.

The sampling and monitoring points for final liquid discharges are on the final discharge line of the TER [NLWDS] and the SEL [LWDS (CI)], and are shown in F-5.5-5. And more information is provided in section 5.5.3.

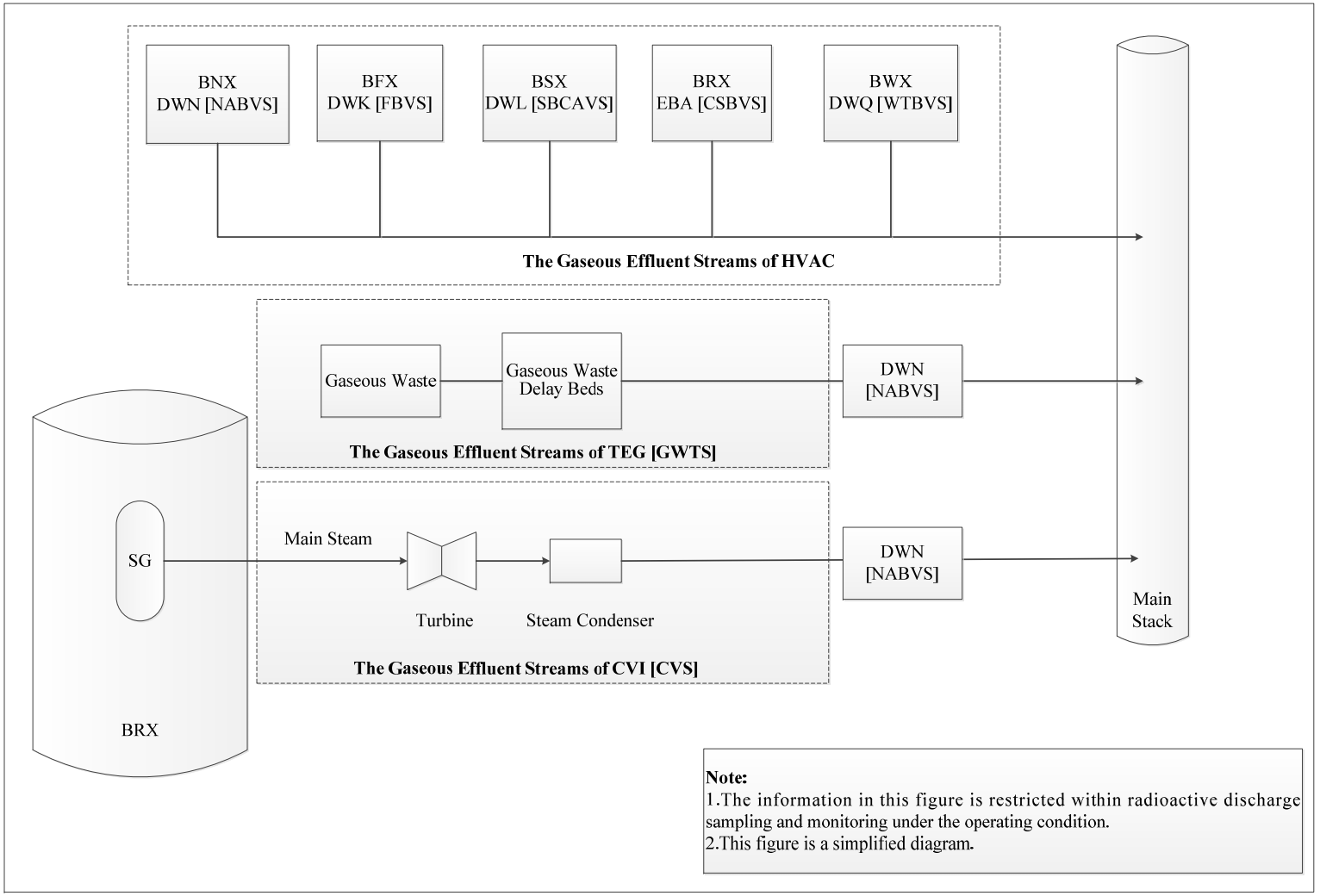
The in-process sampling and monitoring locations for the liquid effluents generated in the different systems are shown in F-5.5-5, F-5.5-6, F-5.5-7, and F-5.5-8.

c) Solid and non-aqueous liquid waste

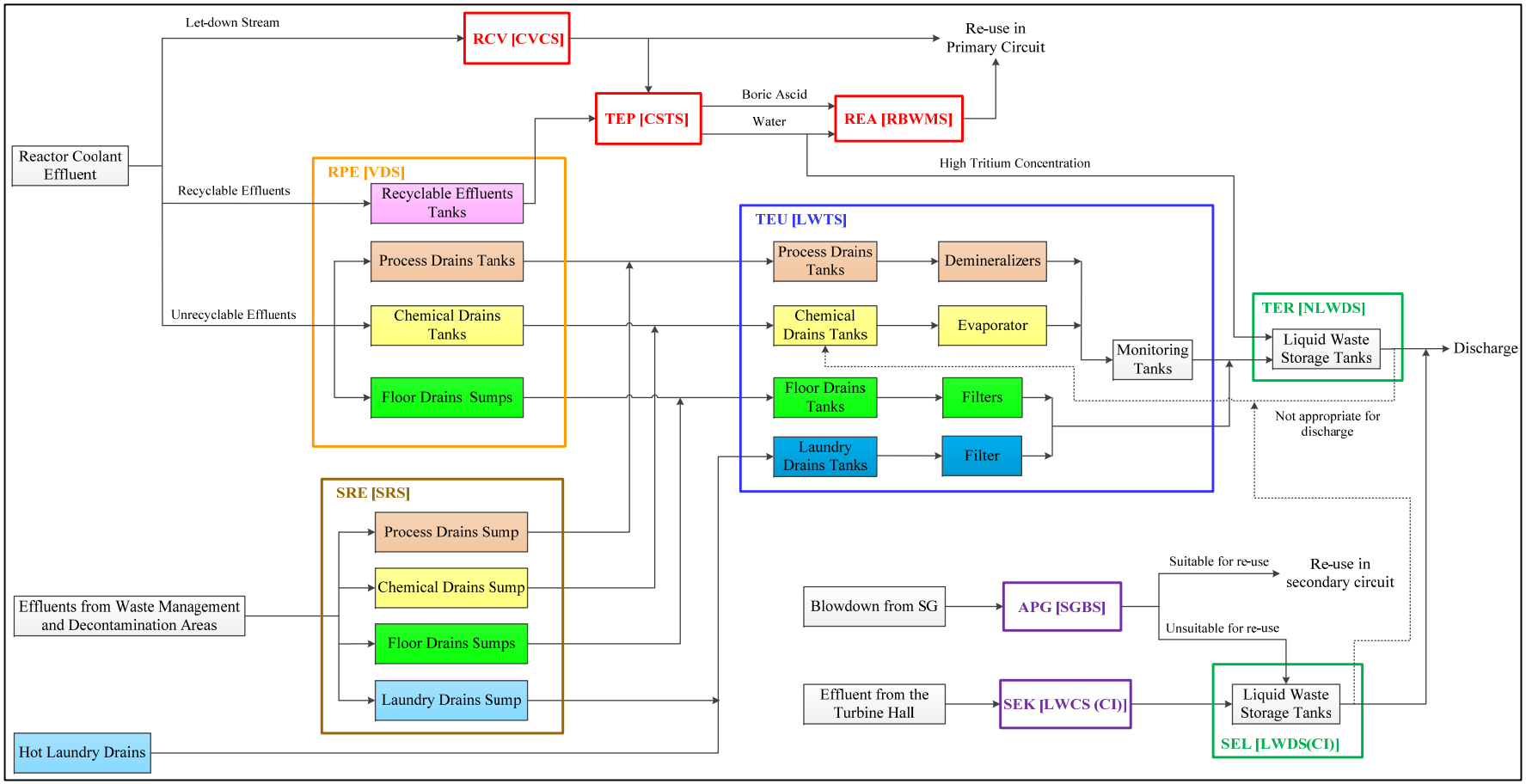
The solid and non-aqueous liquid wastes are managed by the Solid Waste Treatment System (TES [SWTS]). The TES [SWTS] serves to collect, characterise and segregate, treat, condition, package and store the various types of the solid radioactive wastes generated in normal operation. These include spent resins, concentrates, spent filter cartridges, ventilation filter cartridges, dry active waste, as well as the In-core Instrumentation Assembly (ICIA), the Rod Cluster Control Assembly (RCCA), and the Stationary Core Component Assembly (SCCA).

Non-aqueous liquid wastes (including oil and organic solvent) are excluded from the aqueous liquid treatment systems and require export from site to the off-site facility if appropriate treatment is available. Their management is therefore considered alongside the solid radioactive waste. Monitoring of the spent fuel is out of scope of this document and the high level requirements are described in Sub-chapter 6.6 in *Spent Fuel Interim Storage Facility Design*, Reference [22].

The management of the solid and non-aqueous liquid wastes is shown in F-5.5-3. Sampling and monitoring are arranged in different processes.

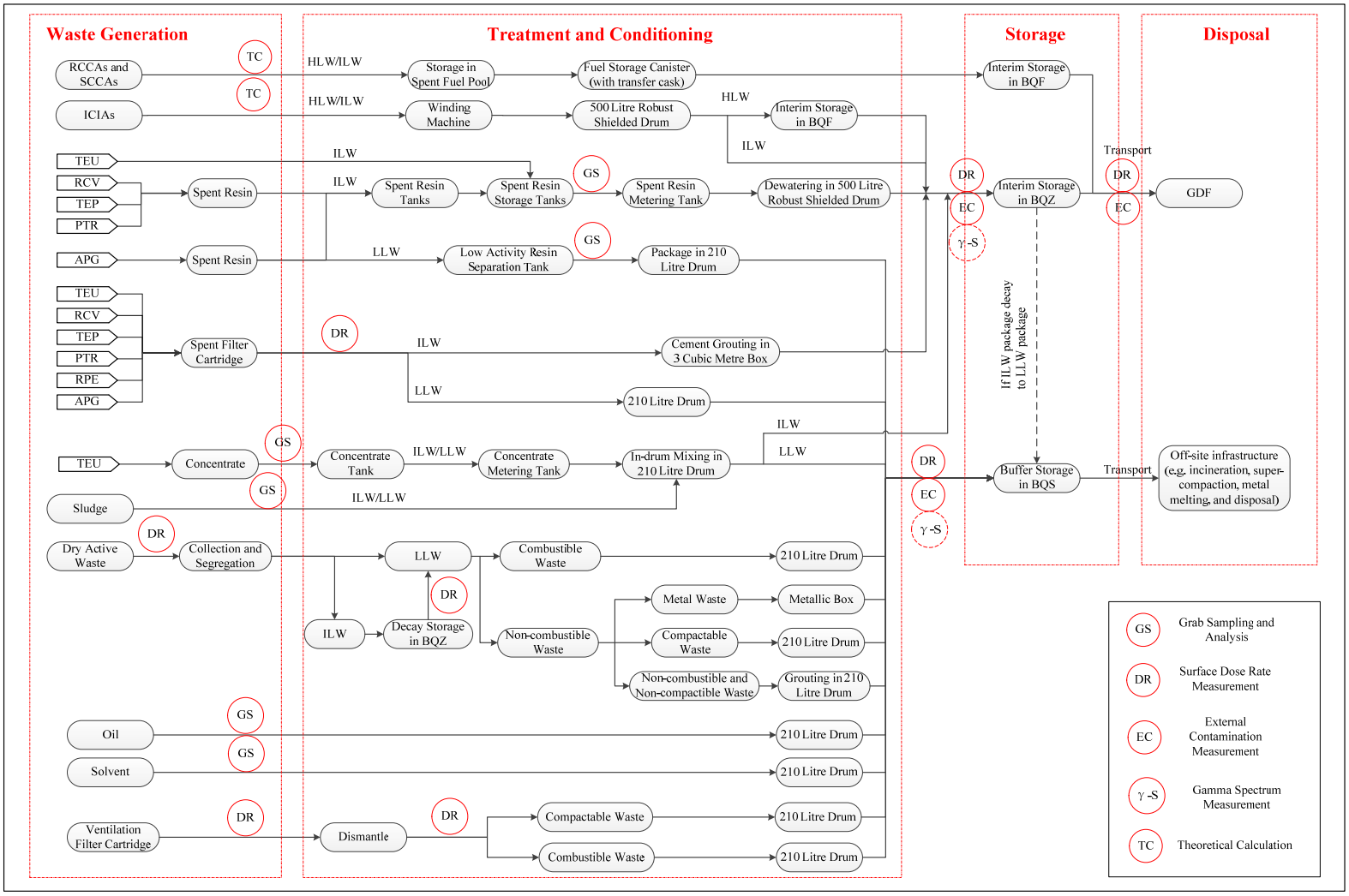



F-5.5-1 Overview of the Gaseous Effluent Routes

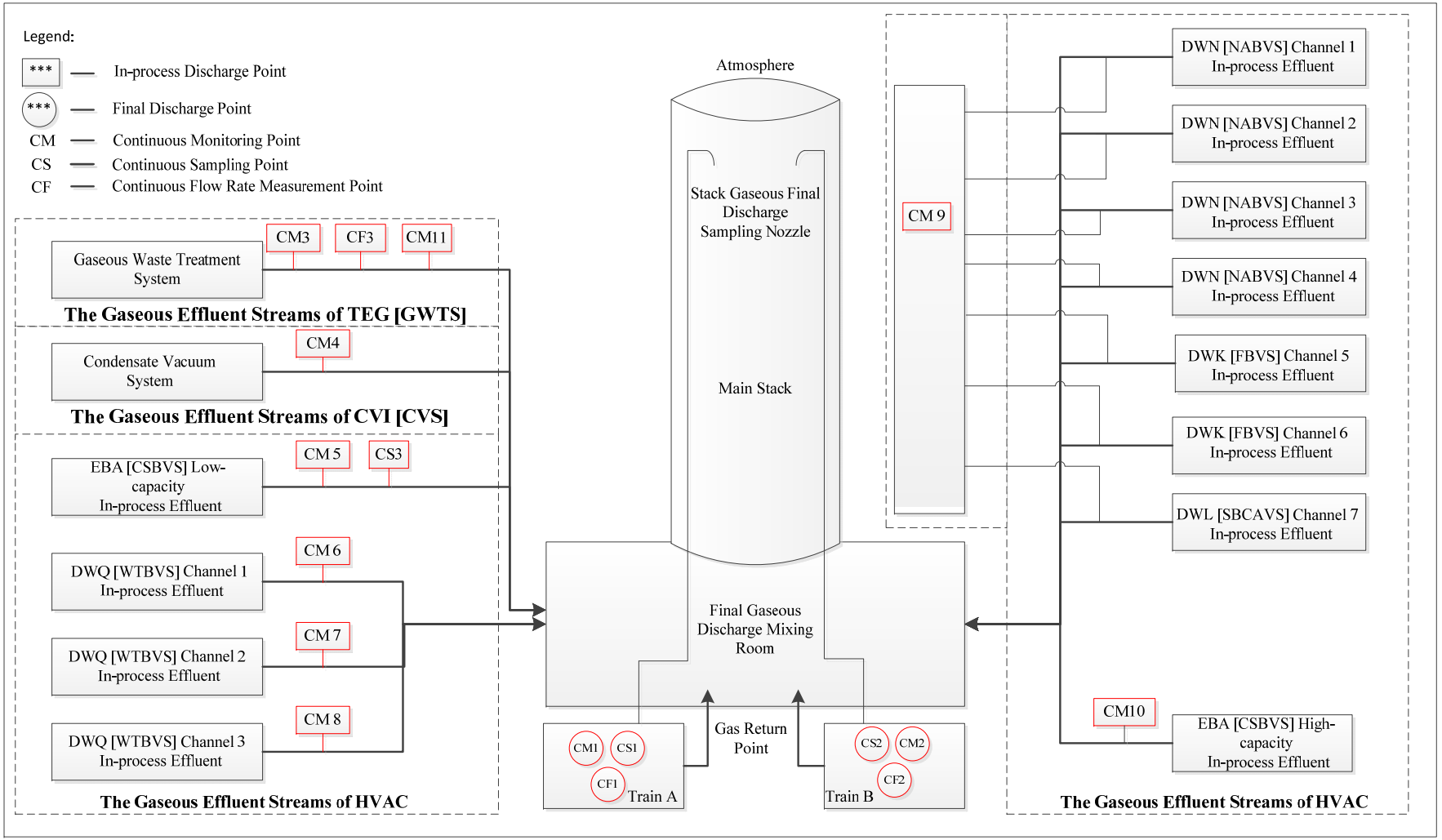



*The following systems presented in this figure are in the scope of the PCER Chapter 5: TEP [CSTS], TEU [LWTS], APG [SGBS], TER [NLWDS] and SEL [LWDS (CI)]

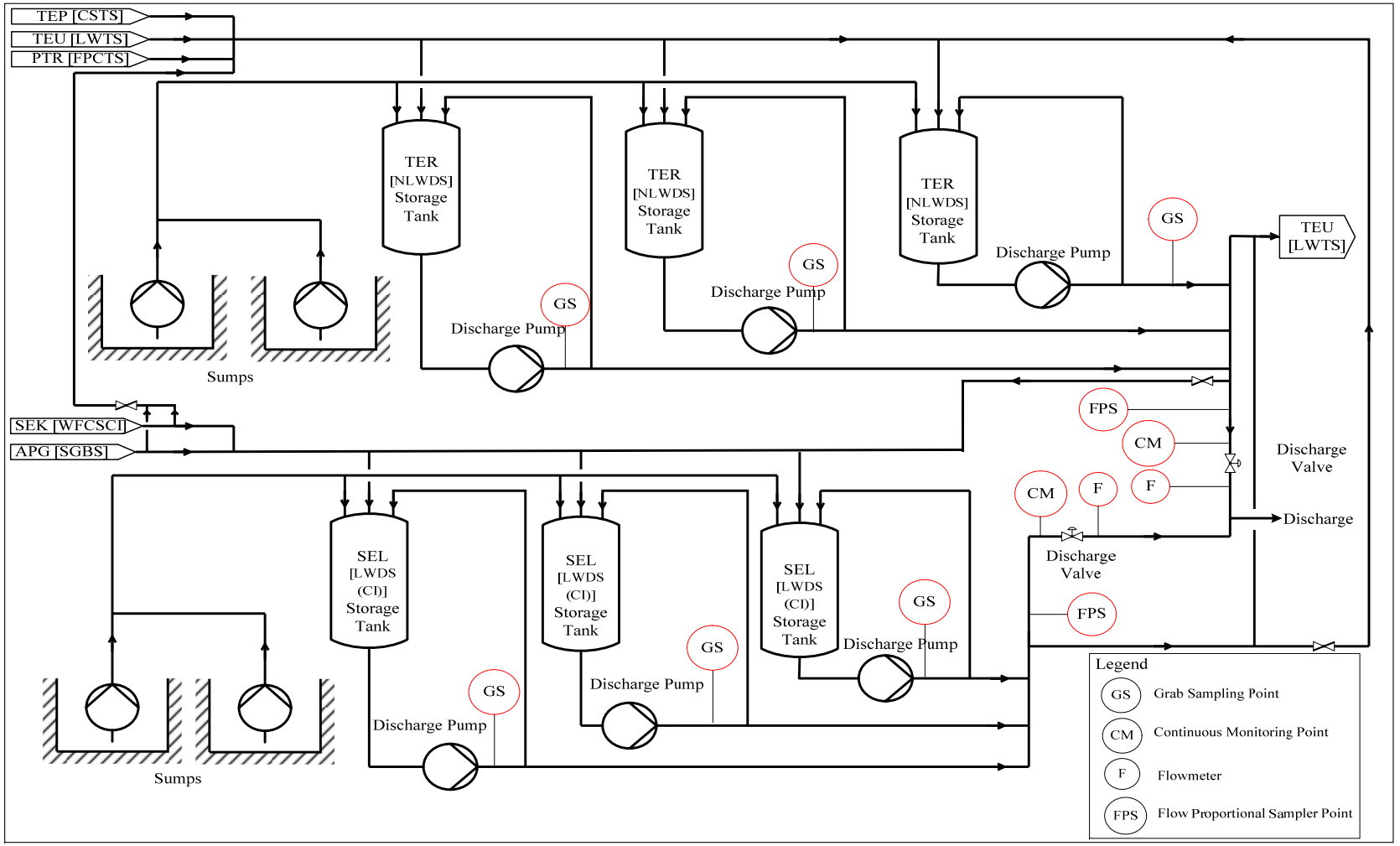
F-5.5-2 Overview of the Liquid Effluent Routes



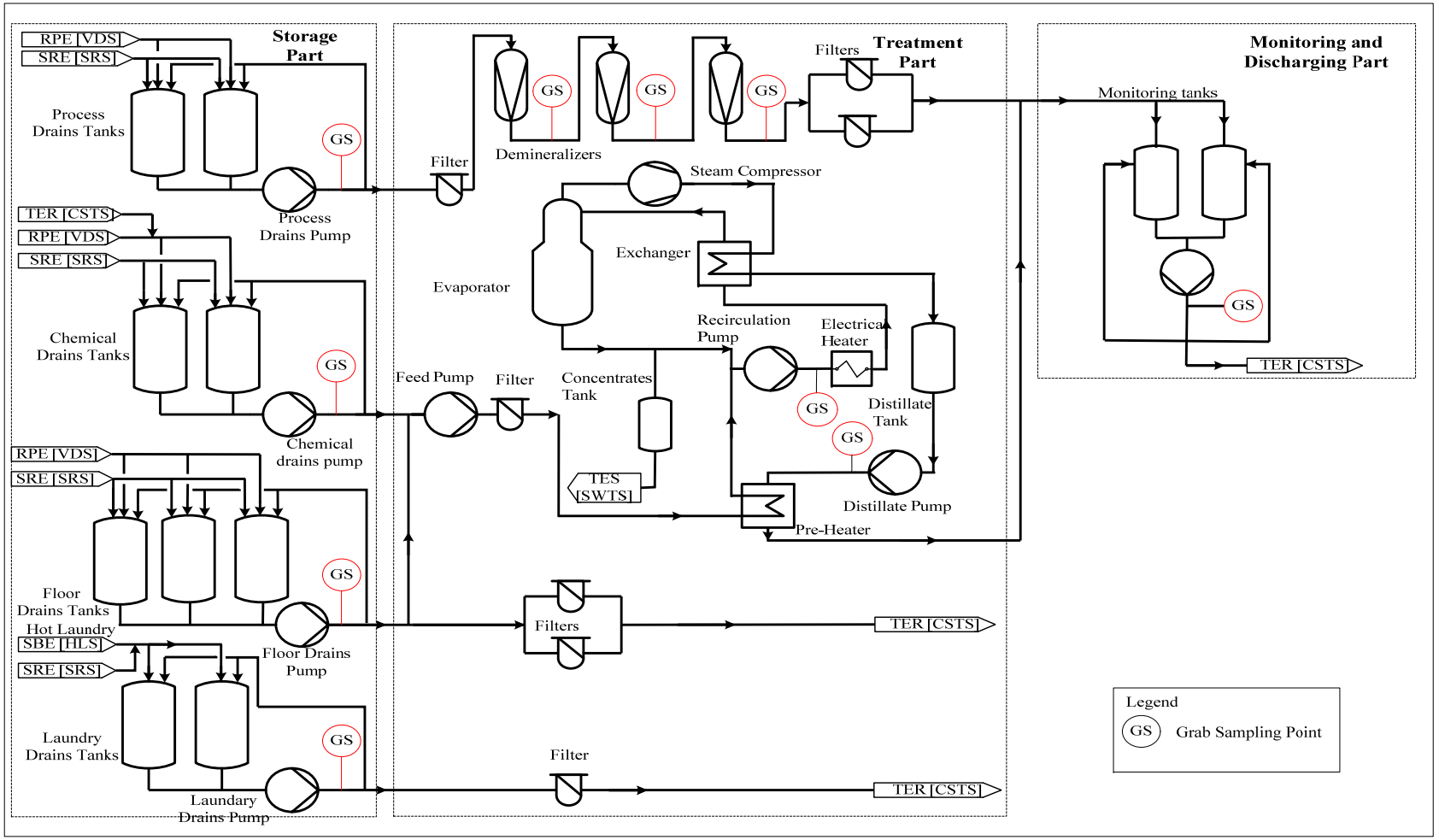

F-5.5-3 Overview of Sampling and Monitoring of the Solid Wastes and Non-aqueous Liquid Wastes



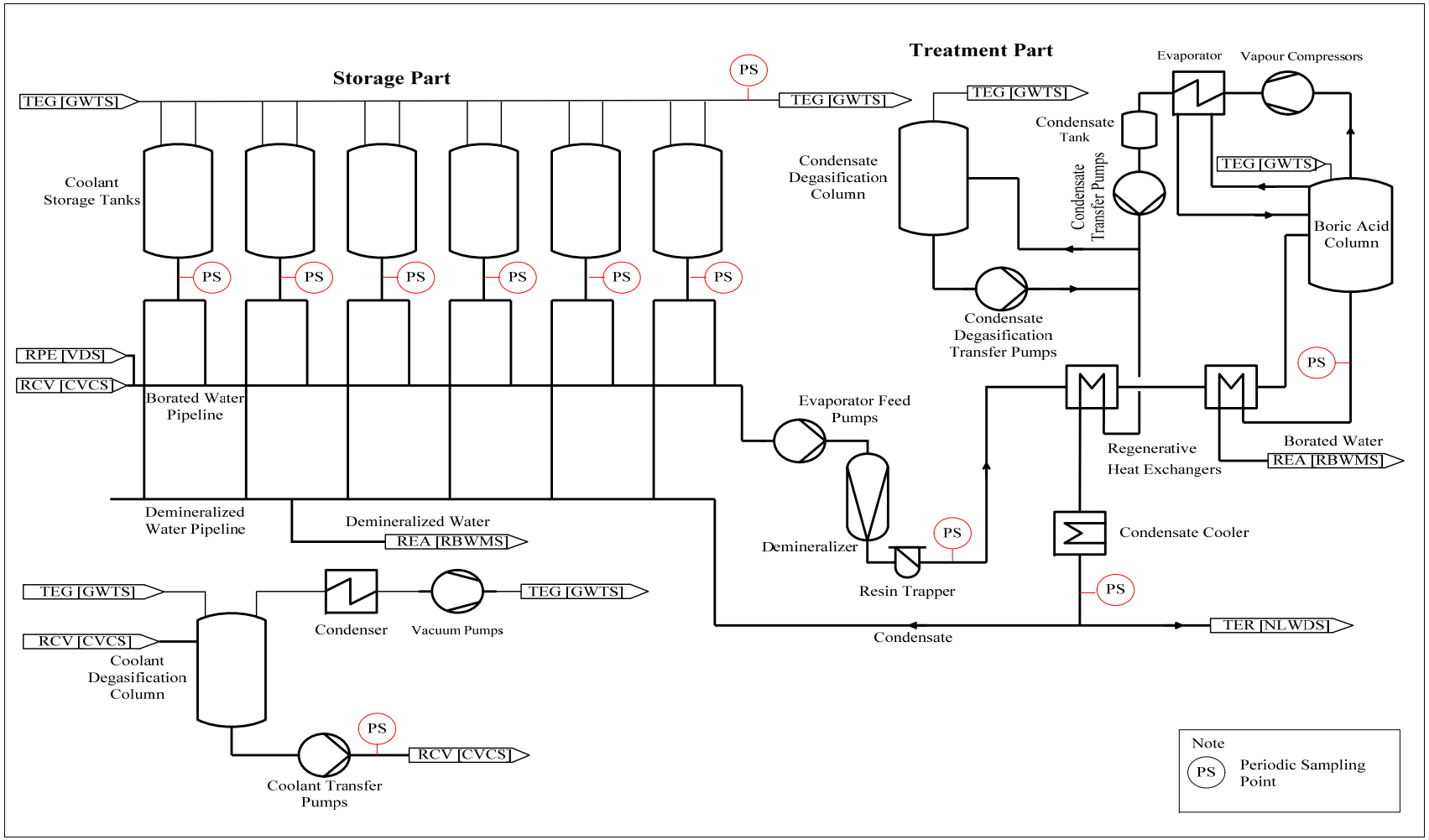

F-5.5-4 In-process and Final Monitoring Points for Gaseous Discharge



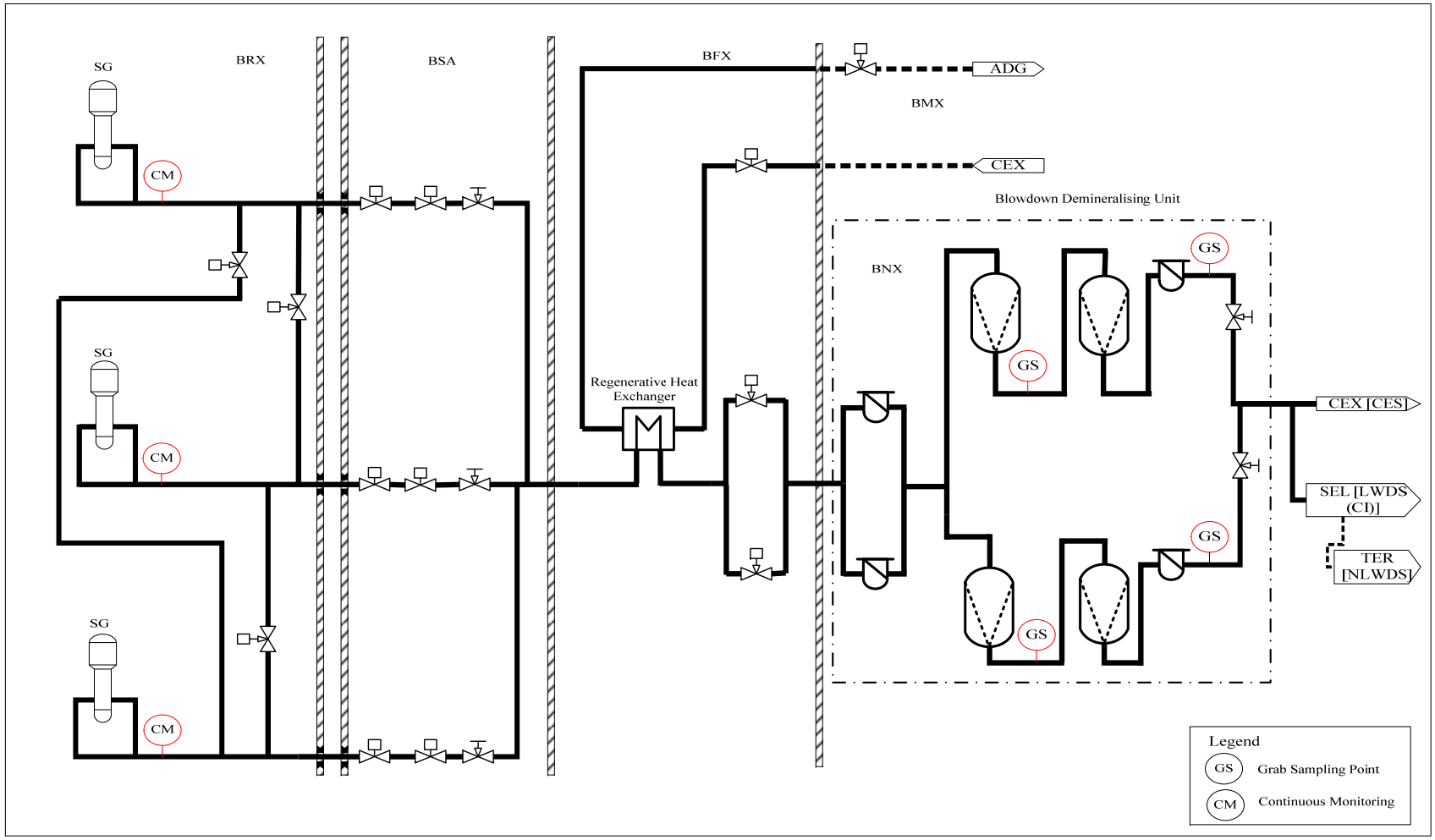

F-5.5-5 In-process Sampling and Monitoring Points in the TER [NLWDS] and the SEL [LWDS (CI)]




F-5.5-6 In-process Sampling and Monitoring Points in the TEU [LWTS]




F-5.5-7 In-process Sampling and Monitoring Points in the TEP [CSTS]




F-5.5-8 In-process Sampling and Monitoring Points in the APG [SGBS]

### 5.5.2 Final Sampling and Monitoring (Gaseous Discharges)

The sampling and monitoring design of the gaseous discharges via the discharge stack for the UK HPR1000 is shown in F-5.5-9. Before feeding into the stack, gaseous effluent is filtered through pre-filters and High Efficiency Particulate Air (HEPA) filters and iodine traps if needed. The sampling and monitoring system is duplicated, Train A and Train B as shown in F-5.5-9. Each train samples or measures the radionuclides or group of radionuclides listed in T-5.5-1.

Each train consists of a common single point shrouded nozzle, sampling pipe, sampling equipment, monitoring equipment, and return pipe. The sample is continuously extracted from the discharge stack, and then passes through filters or absorbers in a dedicated sampling equipment room and finally returns to the mixing room under the discharge stack, as shown in F-5.5-4.

The effect of the return air on sampling is negligible according to the following aspects:

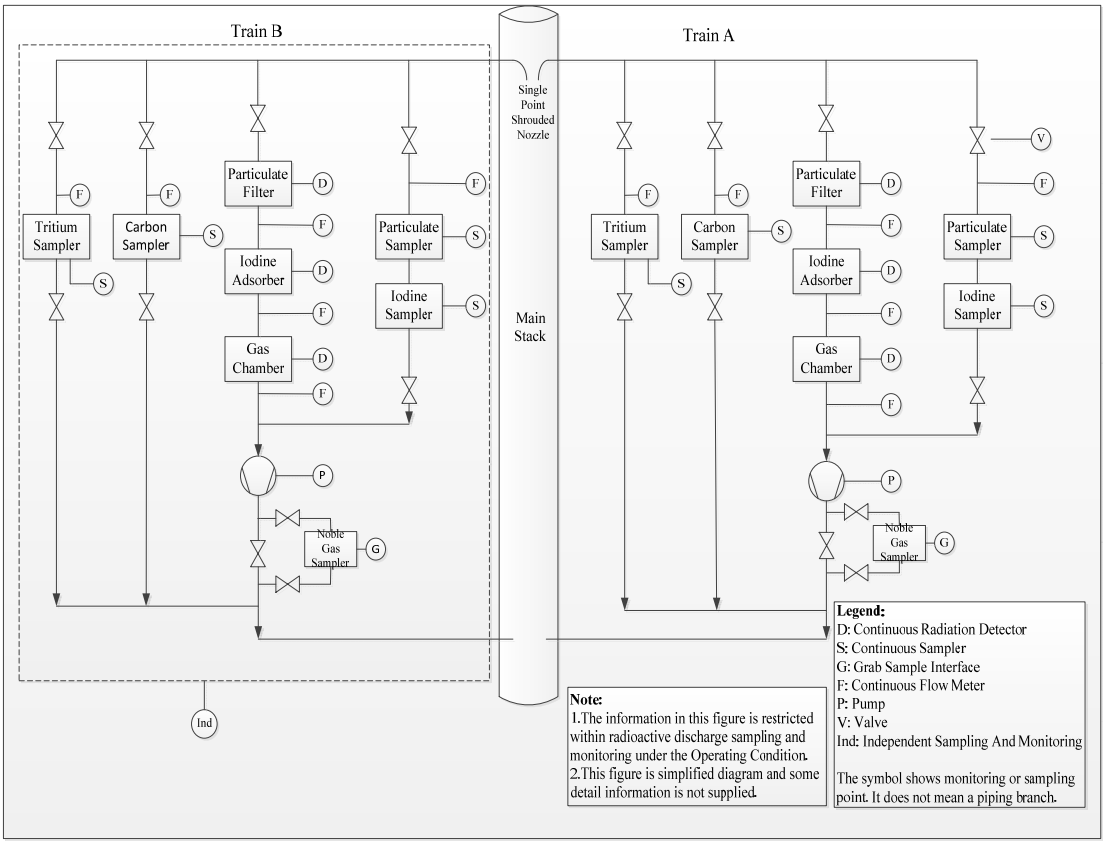
a) The return position is far away from the sampling point. The sampling elevation is 54.75 m and return line is under mixing room about 29 m;

b) Mixing room can mix the return air with exhaust. Return air cannot affect the flow field of the sampling point;

c) The exhaust flow is 1.0E+08 times higher than return air flow.

The aerosol, iodine, noble gases are monitored continuously. At the same time, aerosol, iodine, tritium and carbon-14 are sampled continuously, while the noble gases are sampled by grab sampling. All the samples are sent to the laboratory for accurate measurement.

The monitors and samplers are located in the rooms where the dose rate is low and is easy to access. The representativeness analysis is described in Sub-chapter 5.7.




F-5.5-9 Gaseous Sampling and Monitoring Design in the UK HPR1000

T-5.5-1 Sampling and Monitoring of the Gaseous Discharges

| Radionuclides | Online Monitoring | Sampling and Analysis |
|---|---|---|
| Aerosol | Continuous monitoring | Continuous sampling/<br>Periodic laboratory analysis (two weeks) |
| Iodine | Continuous monitoring | Continuous sampling/<br>Periodic laboratory analysis (two weeks) |
| Noble gases | Continuous monitoring | Periodically sampling/<br>Periodic laboratory analysis (two weeks) |
| Tritium | --- | Continuous sampling /<br>Periodic laboratory analysis (two weeks) |

| Radionuclides | Online Monitoring | Sampling and Analysis |
|---|---|---|
| Carbon-14 | --- | Continuous sampling / Periodic laboratory analysis (two weeks) |

5.5.2.1 Discharge Flow

To calculate the radioactivity of the gaseous discharges, two MCERTS approved flowmeters are arranged inside the stack to measure the volumetric flow. The flowmeters are located near the well mixed region to prevent airflow instability influence on the measurement results. Measurement error of the effluent flowmeter should not be more than 10%. Meanwhile, the sampling devices that are also equipped with continuous flow meters should also have a measurement error no more than 10%. There is a platform that provides safe access for flowmeters periodic inspection and maintenance. Information on stack platform is supplemented by the content of the *Stack Platform Design Report*, Reference [23], which demonstrates the stack platform is effective to support the periodic inspection and maintenance of the flowmeters and provides information on the stack platform design requirements and compliance analysis with relevant codes TGN M1 and standards.

5.5.2.2 Aerosol

It is necessary to continuously monitor the aerosol radioactivity level to prevent abnormal discharges of aerosol to the environment. Aerosol extracted from the discharge stack is filtered by filter paper. The alpha and beta radiation emitted by the particulate matter is then detected by the online KRT [PRMS] monitors. Operators can be informed in a timely manner about any increase of the radioactivity being discharged. The detector's type is expected to be Passivated Implanted Planar Silicon (PIPS).

In addition, the air is extracted continuously from the discharge stack and is sent to the aerosol sampling device. The aerosol is filtered and deposited on a filter paper which is sent periodically to laboratory for analysis.

5.5.2.3 Iodine

It is necessary to continuously monitor the iodine radioactivity level to prevent abnormal discharges of iodine to the environment. Air extracted from the discharge stack is sent to the iodine activity measurement channel after the filtration of the aerosol. The iodine is then absorbed by the activated charcoal. An online KRT [PRMS] monitor is used to measure the gamma ray emitted by the iodine. Operators can be informed in a timely manner about any increases of the radioactivity being discharged. The detector's type is expected to be NaI.

In addition, the air is extracted continuously from the discharge stack and is sent to

the iodine sampling devices after filtration of the aerosol. The iodine is absorbed by activated charcoal which is sent periodically to laboratory for analysis.

5.5.2.4 Noble Gases

It is necessary to continuously monitor the noble gases radioactivity level to prevent abnormal discharges of noble gases to the environment. Air extracted from the discharge stack is sent to the noble gases activity measurement channel after the aerosol filtration. The radioactivity of the noble gases is then measured by the online KRT [PRMS] monitors. Operators can be informed in a timely manner about any increases of the radioactivity being discharged. The detector's type is expected to be PIPS.

In addition, noble gases are collected periodically for laboratory analysis using a fixed volume chamber after removal of any potential aerosol material and iodine.

5.5.2.5 Tritium and Carbon-14

It is necessary to continuously sample the tritium and carbon-14 to monitor discharges to the environment. The air is extracted continuously from the discharge stack and the aerosol is filtered by the build-in filters, and the filtered air is then sent to the tritium and carbon-14 sampling units which are expected to be bubbler systems.

5.5.2.6 Sampling Flow

For the purpose of the activity calculation, accumulative volumetric flow is measured in each sampling line. In addition, in order to keep the constant sampling conditions, volumetric sampling flow rate is measured. If the flow rate is lower than the threshold value, then an alarm is triggered.

### 5.5.3 Final Sampling and Monitoring (Liquid Discharges)

For the UK HPR1000, there is a single discharge point used for the discharge of liquid radioactive effluents.

As mentioned in section 5.5.1, the liquid radioactive waste is discharged to the environment by the TER [NLWDS] and the SEL [LWDS (CI)]. As shown in F-5.5-5, there are three types of sampling and monitoring arrangements implemented in these two systems, including grab sampling, continuous monitoring and a flow proportional sampler. The continuous monitoring and the flow proportional sampler are used for final monitoring and sampling respectively. The grab sampling is used as an in-process sampling for the TER [NLWDS] and the SEL [LWDS (CI)], which is described in section 5.5.6.

Two final online continuous monitors are arranged on the discharge lines of the TER [NLWDS] and the SEL [LWDS (CI)] respectively to measure the radioactive concentration of the total gamma emitted by the liquid radioactive waste. If the measured radioactive concentration exceeds the set threshold (to be defined at site

specific stage) or a failure of the gamma detector is detected, an alarm will be activated and the automatic discharge isolation valve will be closed. This will stop the discharge to the environment. A manual valve is also fitted to enable the operator to initiate a stop of the discharge if required.

Final samples are collected from the discharge line of the TER [NLWDS] and the SEL [LWDS (CI)] through the use of a flow proportional sampler. There are two flow proportional samplers on the discharge lines, one on the TER [NLWDS] and the other on the SEL [LWDS (CI)]. Flow proportional samplers are used to collect representative samples during discharge. The flow rate of the discharge is also measured in the discharge line of each system.

### 5.5.4 Solid Waste and Non-aqueous Liquid Waste Sampling and Monitoring

According to the principles of radioactive waste management in the UK, Reference [24], [25] and [26], characterisation of the radioactive waste should be performed in several locations, processes and management steps so as to ensure that subsequent management is safe, efficient, optimised and effective.

The requirements for and arrangements of the sampling and monitoring will vary according to the management process as well as the type of waste. For the UK HPR1000, the arrangements for monitoring and sampling of solid and non-aqueous liquid waste are as follows:

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

   1) For homogeneous solid and non-aqueous liquid waste, including spent resins, concentrates, sludge, oil and organic solvent, the samples are taken at or close to the generation point for further laboratory analysis.

   2) For heterogeneous wastes, including spent filter cartridges (including the water and ventilation filter cartridges) and dry active waste, the dose rate and /or gamma spectrum are measured at the generation point. Sampling of these types of solid waste is either difficult to perform, not ALARP[1] or is uneconomical due to the relatively high quantity of waste.

b) **Before processing**: Before the waste is processed/packaged, the radiological information is required to ensure that the waste to be packaged and the resulting waste packages will comply with relevant criteria such as the waste acceptance criteria of the off-site treatment or disposal facilities. For some radioactive waste

[1] Methods involving retrieving a physical sample of filtering media for example is not deemed ALARP/BAT because it would involve drilling or cutting of the filter cartridges which would induce high doses to personnel and release of radioactive material (notably to air), notably for ILW filters.

streams, measurements done at or close to generation point will be used directly as processing / packaging will take place immediately after production. For waste which will be stored before being processed or packaged, the same sampling and monitoring arrangements as those at or close to the generation point will be used to reassess the radiological characteristics of the waste. The results obtained at or close to the generation point can alternatively be used and corrected as relevant to account for the decay during the storage time.

c) **After processing, before and during Storage**: Once the waste is packaged, the waste package is usually stored on-site before being transferred to the off-site treatment or disposal facilities:

- For Low Level Waste (LLW), this storage period is to be short and the relevant storage area is to be close to the waste processing/packaging plants;
- For Intermediate Level Waste (ILW), High Level Waste (HLW) (and spent fuel), this storage period is expected to be relatively long as the intended disposal facility for these waste packages (the Geological Disposal Facility (GDF)) will only be available in many decades in the future. Dedicated on-site storage facilities, namely the ILW Interim Storage Facility (BQZ) and Spent Fuel Interim Storage Facility (BQF), are therefore being developed for the interim storage of these waste packages;
- For ILW/LLW boundary waste, the storage period is expected to be less than 20 years and will be determined by the decay time needed for the waste, initially ILW, to decay to LLW. This decay storage will take place in the BQZ.

The monitoring of the solid waste packages and the non-aqueous liquid waste packages after processing, and before and during storage is carried out to:

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

- Understand, at all time, the inventory of the radioactive wastes that stored on-site.

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

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

The arrangement and locations of sampling and monitoring for the solid and non-aqueous liquid wastes are presented in F-5.5-3 and summarised in T-5.5-2. In addition to the sampling and monitoring of the solid and non-aqueous liquid waste / waste packages, calculations can also be carried out as and where relevant, using dedicated codes or simpler methods, for example, for the ICIA, RCCA and SCCA, theoretical method is used. Information from sampling and monitoring of the liquid and gaseous waste can also be used for solid waste characterisation purposes.

T-5.5-2 Sampling and Monitoring Arrangements for Solid and Non-aqueous Liquid Wastes

| Waste Types | Characterisation Method[2] |
|---|---|
| Spent resins | Sampling and laboratory analysis close to the generation point and before conditioning/packaging;<br>Dose rate and external contamination measurement for the waste packages at all management steps. |

[2] For the radionuclides that are difficult to measure directly, the scaling factor method, Reference [27] and dose rate method can be applied. The scaling factor method is a method for evaluating the radioactivity of defined difficult-to-measure radionuclides from the radioactivity of key radionuclides, based on the correlations between the difficult-to-measure radionuclides and key radionuclides. The dose rate method evaluates the radioactivity of the defined radionuclide from the dose rate of waste package, based on the relationship between the dose rate and a pre-determined gamma spectrum.

| Waste Types | Characterisation Method[2] |
|---|---|
| Concentrates | Sampling and laboratory analysis at the generation point and before conditioning/packaging;<br>Dose rate, external contamination and gamma spectrum measurement for the waste packages at all management steps. |
| Sludge | Sampling and laboratory analysis at the generation point and before conditioning/packaging;<br>Dose rate, external contamination and gamma spectrum measurement for the waste packages at all management steps. |
| Non-aqueous liquid wastes | Sampling and laboratory analysis at the generation and before conditioning/packaging;<br>Dose rate, external contamination and gamma spectrum measurement for the waste packages at all management steps. |
| Spent filter cartridges | Dose rate measurement at the generation point and before conditioning;<br>Dose rate, external contamination and gamma spectrum measurement for the waste packages at all management steps. |
| Ventilation filter cartridges | Dose rate measurement at the generation point;<br>Dose rate measurement after dismantling (if dismantling is carried out);<br>Dose rate, external contamination and gamma spectrum measurement for the waste packages at all management steps. |
| Dry active waste | Dose rate measurement at the generation point and before conditioning/packaging;<br>Dose rate, external contamination and gamma spectrum measurement for the waste packages at all management steps. |
| ICIA, RCCA and SCCA | Theoretical calculation at the generation point and before conditioning/packaging. |

### 5.5.5 In-process Sampling and Monitoring (Gaseous Effluents)

The radiation level of the gaseous effluent is continuously monitored before feeding into the discharge stack. This continuous monitoring is undertaken to quantify the contributions from the different buildings to the discharges to the discharge stack, and to identify the source of an elevated discharge under anticipated operational

occurrences.

There are three types of in-process sampling and monitoring corresponding to three gaseous effluent streams as shown in F-5.5-1.

The first one is monitoring of the gaseous effluents in the HVAC system discharged from buildings which may contain radioactive material. The purpose of this monitoring is to provide information on the gaseous radioactivity inside the buildings and to indicate whether there is any leakage of radioactive matter. If the gaseous activity concentration reaches the alarm threshold, a sound-light alarm is triggered locally. The analog information and all alarms are sent to and displayed in the main control room. At the same time, the HVAC system line is switched to the iodine filtration train. Plant operators will investigate the room where the radioactive matter leakage is and take appropriate action. Measurement data is displayed and recorded in the main control room.

The second one is the monitoring of the gaseous effluents in the TEG [GWTS]. This monitoring is undertaken to measure the activity concentration in gaseous discharges from the delay beds. If the gaseous activity concentration reaches the set alarm threshold, a sound-light alarm is triggered locally. The analog information and all alarms are sent to and displayed in the main control room. Plant operators will investigate the situation and take appropriate action. Measurement data is displayed and recorded in the main control room.

The third one is the monitoring of the steam generator tube integrity. This monitoring is undertaken to detect any leakage of high activity into secondary circuit. The main steam is condensed in the condenser and the radioactivity of the non-condensable noble gases (in the CVI [CVS]) is monitored. If the activity of the non-condensable noble gases reaches the set alarm threshold, a sound-light alarm is triggered locally. The analog information and all alarms are sent to and displayed in the main control room. Plant operators will check and take appropriate action. Measurement data is displayed and recorded in the main control room. Because this monitoring channel is used to detect steam generator tube rupture which is outside the scope of this chapter, the information presented in this section is only to show that all the inputs are monitored before the discharges feed into the discharge stack.

The in-process sampling and monitoring points are shown in F-5.5-4. T-5.5-3 shows the monitoring techniques for the different ventilation systems. Information is presented on the parameters to be monitored and the expected detector type. The parameters to be monitored are selected according to the radiological risk of the system.

T-5.5-3 In-Process Monitoring Ventilation Systems and Monitoring Technique

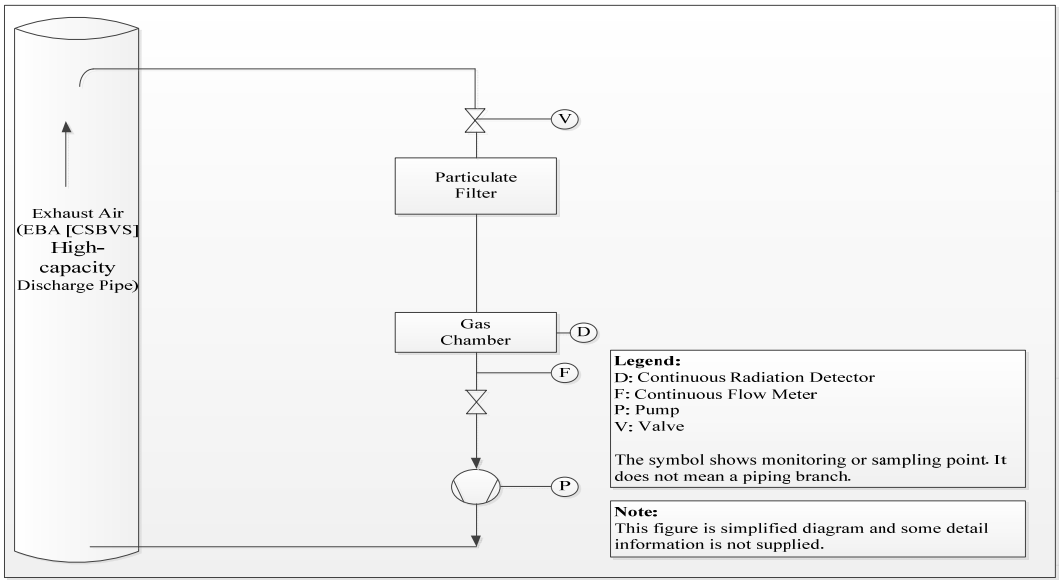
| Ventilation System | Monitoring Object | Expected Detector Type |
|---|---|---|
| EBA [CSBVS] | Noble Gases | PIPS |
| DWK [FBVS] | Noble Gases | Differential Ionisation Chamber |
| DWN [NABVS] | Noble Gases | Differential Ionisation Chamber |
| DWL [SBCAVS] | Noble Gases | Differential Ionisation Chamber |
| DWQ [WBVS] | Aerosol/Iodine | NaI/PIPS |
| TEG [GWTS] | Noble Gases | NaI/PIPS |

5.5.5.1 Monitoring of Exhaust Air from the Nuclear Island Ventilation System

The exhaust air from the EBA [CSBVS], the DWK [FBVS], the DWN [NABVS] and the DWL [SBCAVS] are collected in the air collection room, where they are mixed and sent to the discharge stack for release to the environment. Monitoring points are arranged on the discharge pipelines of the ventilation systems mentioned above to measure the activity concentration. The monitoring channels and sampling devices include:

a) Monitoring channel (point CM10 in F-5.5-4) for EBA [CSBVS] high-capacity exhaust air

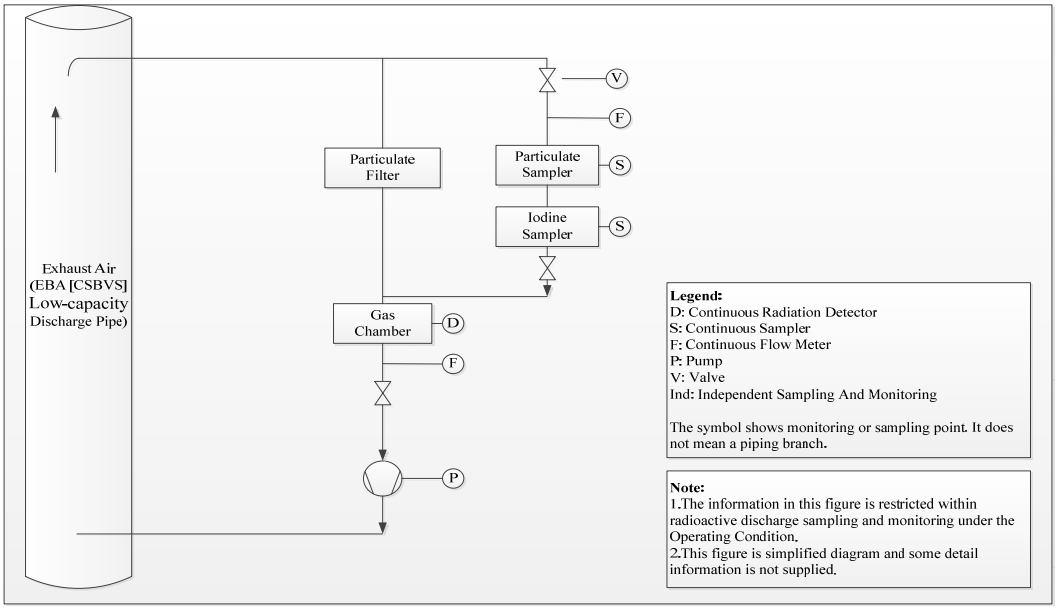
   Under reactor shutdown conditions, the air extracted from the EBA [CSBVS] high-capacity discharge pipe is sent to the KRT [PRMS] noble gases measurement equipment after the aerosol filtration. The activity concentration of the noble gases is measured online by a beta/gamma sensitive detector (PIPS). The process is shown in F-5.5-10. The monitor is located in an easily accessible room where the dose rate is low.




F-5.5-10 EBA [CSBVS] High-capacity Exhaust Air Monitoring Flow Diagram

b) Monitoring and sampling channels (point CM5 and CS3 in F-5.5-4) for EBA [CSBVS] low-capacity exhaust air

Air extracted from the EBA [CSBVS] low-capacity discharge pipe is monitored for noble gases after aerosol filtration. A KRT [PRMS] beta/gamma detector is used to measure the beta and gamma rays emitted by the noble gases. In addition, aerosol and iodine sampling devices are arranged to take samples for laboratory analysis. The detector type is expected to be a PIPS and the sampler type is expected to be Particle and Iodine Sampler (PIS). The process is shown in F-5.5-11. The monitors and samplers are located in an easily accessible room where the dose rate is low.

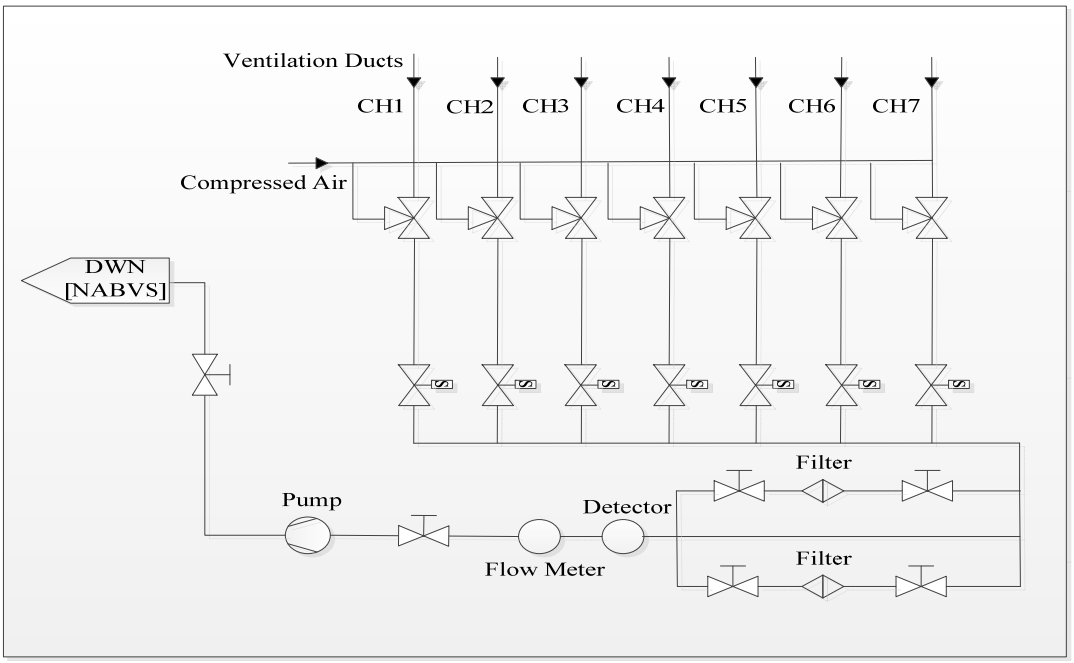



F-5.5-11 EBA [CSBVS] Low-capacity Exhaust Monitoring Flow Diagram

c) Monitoring channels (point CM9 in F-5.5-4) for DWN [NABVS], DWK [FBVS] and DWL [SBCAVS] exhaust air

The air extracted from the two trains of the exhaust pipe of the DWK [FBVS], from the four trains of the exhaust pipe of the DWN [NABVS] and from the one train of exhaust pipe of the DWL [SBCAVS] is sent to the KRT [PRMS] for noble gases measurement after aerosol filtration. The process is shown in F-5.5-12.

A beta/gamma sensitive detector is used to measure the beta and gamma rays emitted by the noble gases in the exhaust air. Continuous measurement of these seven sampling channels is made by scanning or of only one if abnormal activity detected on it. Any one of the channels can be ever kept into memory. The scanning time of a line is less than three minutes. The detector type is expected to be a differential ionisation chamber. The monitor is located in an easily accessible room where the dose rate is low.



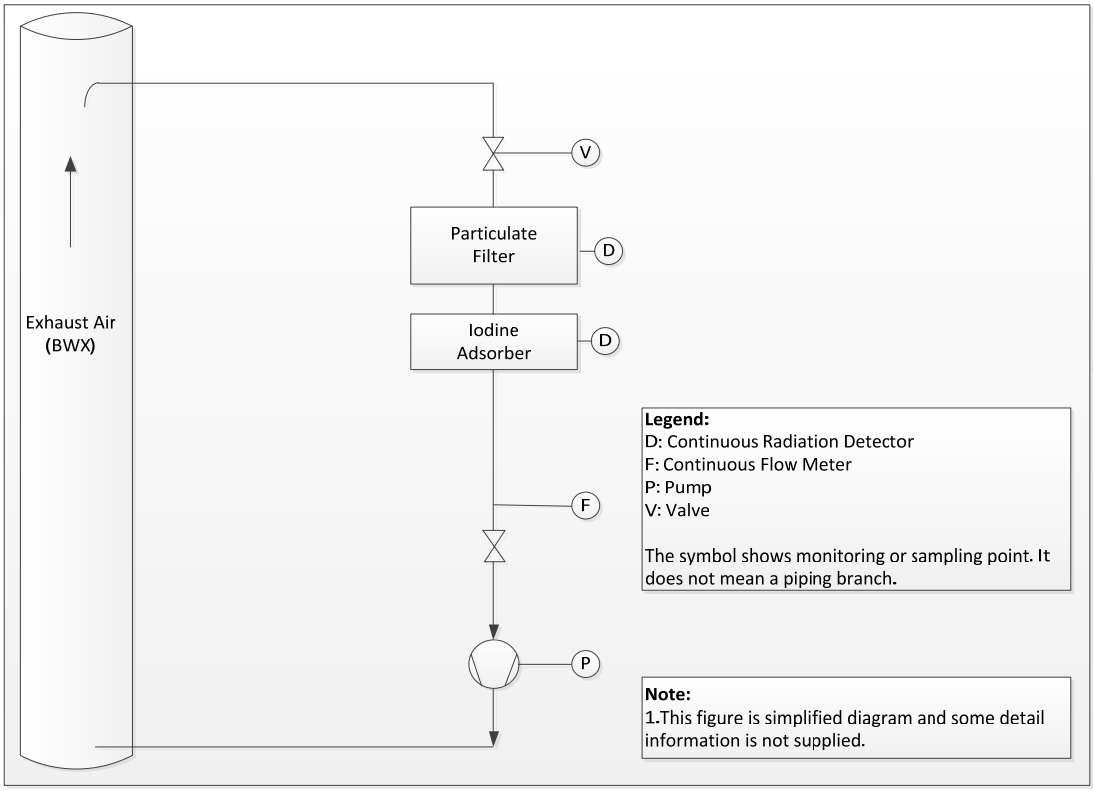

F-5.5-12 Nuclear Island Ventilation System Exhaust Monitoring Flow Diagram

5.5.5.2 Radioactivity Monitoring for the BWX

Radioactivity monitoring is undertaken in the Radioactive Waste Treatment Building (BWX) is to ensure that leaks are detected in a timely manner, and that the operators in the BWX are protected radiologically.

Monitoring channels for aerosols and iodine (point CM6 in F-5.5-4) are arranged in the DWQ [WBVS] train 1 of the BWX since this train serves for rooms that have aerosol and iodine risk. Aerosol monitoring channels (point CM7 and CM8 in F-5.5-4) are arranged in the DWQ [WBVS] train 2 and train 3 since these two trains serve for rooms that have an aerosol risk. The aerosol detector type is expected to be a PIPS,

and the iodine detector type is expected to be a NaI. The process is shown in F-5.5-13.




F-5.5-13 BWX Building Exhaust Monitoring Flow Diagram

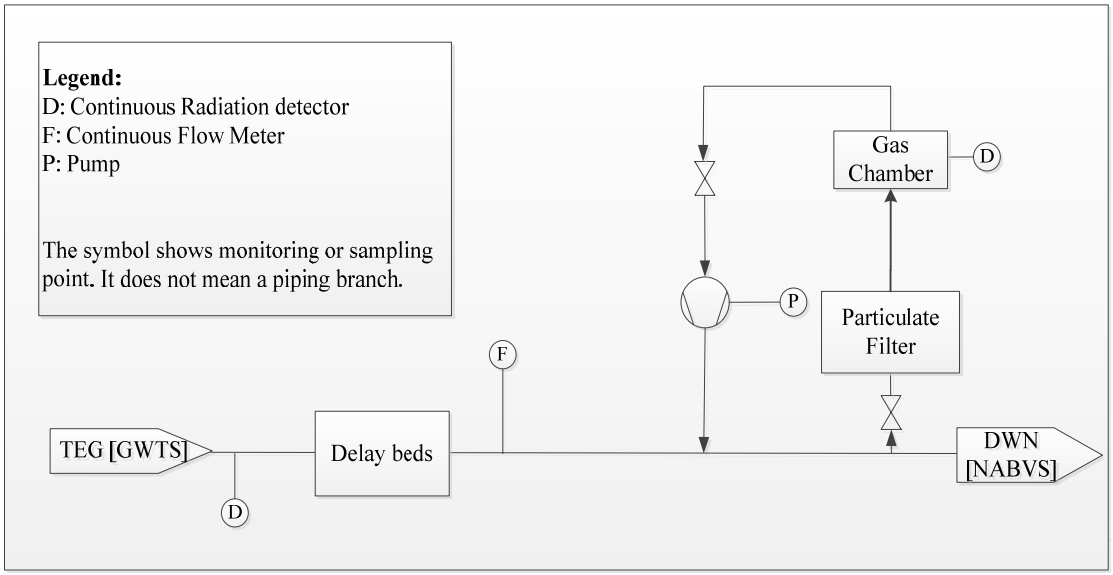
5.5.5.3 Radioactivity Monitoring for the TEG [GWTS]

The operation of the delay beds is monitored by one measuring point upstream and one point downstream, as shown in F-5.5-14.

The upstream measurement point (point CM3 in F-5.5-4) is used to measure the gamma radiation emitted by the radioisotopes entering the delay beds. The detector type is expected to be a NaI. The local processing display unit is located in an easily accessible room where the dose rate is low.

The downstream measurement point (point CM11 in F-5.5-4) is used to measure the radioactivity discharged from the TEG [GWTS]. A beta/gamma sensitive detector is used to measure the radioactivity in the exhaust air after the aerosol filtration. The detector type is expected to be a PIPS. The local process and display unit is located in an easily accessible room where the dose rate is low.

In addition, the discharge flow rate through the TEG [GWTS] is also measured to obtain the gross radioactivity of the discharges from this system.




F-5.5-14 TEG [GWTS] Gaseous Waste Monitoring Flow Diagram

### 5.5.6 In-process Sampling and Monitoring (Liquid Effluents)

In addition to sampling and monitoring of final discharge, in-process sampling and monitoring arrangements are also undertaken for the liquid effluents. This in-process assessment is undertaken for the discharge upstream systems, including the TEU [LWTS], the TEP [CSTS] and the APG [SGBS]. The grab sampling in the TER [NLWDS] and the SEL [LWDS (CI)] is also described in this section.

In-process sampling in the TER [NLWDS] and the SEL [LWDS (CI)] is shown in F-5.5-5.

TER [NLWDS] and SEL [LWDS (CI)]

The aim of the in-process sampling in the TER [NLWDS] and the SEL [LWDS (CI)] is to determine whether the waste in the storage tanks can be discharged to the environment and how it will be discharged.

As shown in F-5.5-5, there are three storage tanks for each system of the TER [NLWDS] and the SEL [LWDS (CI)]. Once the level of liquid effluent in a storage tank within a system reaches a predetermined value, the incoming effluent will be switched to the second tank and the inlet isolation valve on the first tank will be closed. Prior to being discharged, the liquid in the tank is mixed by a pump through a recirculation line. After sufficient mixing has been achieved, a sample is collected at a sampling point, located in the sampling line at the outlet of the discharge pump. Sampling is undertaken during recirculation of the tank. The sampling line is located in area convenient for operators to perform the sampling operation and where the dose rate is low. Liquid effluent removed from the storage tanks for sampling is returned to the tanks.

Once the radioactivity of samples is confirmed to be less than the discharge

management objective, the liquid effluent is pumped to the discharge outfall point where it is discharged to the sea. If the radioactivity of liquid effluent in the storage tanks is higher than the discharge management objective, then appropriate actions will be taken, such as transfer to the liquid effluent to the TEU [LWTS] for re-treatment.

The in-process sampling and monitoring of the liquid effluents arranged in the upstream system of the TER [NLWDS] is shown in F-5.5-6 and F-5.5-7. F-5.5-6 illustrates the sampling and monitoring related to the TEU [LWTS], the F-5.5-7 illustrates the sampling and monitoring related to the TEP [CSTS].

TEU [LWTS]

The TEU [LWTS] is an important system upstream of the TER [NLWDS]. Any abnormal operation and malfunction of the TEU [LWTS] will therefore influence the radioactivity in the liquid transferred to the TER [NLWDS]. Grab sampling is undertaken to measure the radioactivity levels present in this liquid effluent.

The liquid effluents delivered to the TEU [LWTS] are segregated into four separate streams, which optimise the downstream treatment process by enabling the most suitable treatment technology to be selected. As shown in F-5.5-6, the sampling arrangements in the TEU [LWTS] comprise:

a) Before processing, liquid in the storage tanks (process drains tanks, chemical drains tanks, floor drains tanks and laundry drains tanks) is recirculated and subject to sampling for analysis to determine which treatment is to be applied. Samples are collected from a glove box or local sampling funnel located in a low dose rate area, from the sampling line during the recirculation of the tanks. The water drained out during sampling is collected and routed back to the storage tanks in the TEU [LWTS];

b) The effluent downstream of the demineralisers, recirculation pump and distillate pump is sampled to evaluate the performance of the demineralisation unit and evaporation unit. Sample taken from the recirculation pipe of the monitoring tanks as regarded as representative for the purpose of this monitoring objective. The samples taken are used to evaluate whether the effluent meet the discharge management objective. Samples are collected from a glove box or local sampling funnel located in a low dose rate area. The sampling line is as short as possible to ensure that consistent sampling is achieved;

c) The activity and chemical properties of the liquid effluent stream that are treated by demineralisation and evaporation are analysed by sampling from the monitoring tanks before being discharged to the TER [NLWDS]. Samples are collected from a glove box located in low dose rate area via a sampling line during the recirculation of monitoring tanks. To ensure consistent sampling, the sampling line is as short as possible. If the radioactivity and chemical properties of the liquid waste meet the discharge management objective, the liquid effluent

is transferred to the TER [NLWDS]. If it does not meet the objectives, it is routine to the chemical tanks or upstream of the demineralisers for re-process. The effluent treated by filtration is transferred to the TER [NLWDS] directly where it will be monitored.

TEP [CSTS]

The TEP [CSTS] is located upstream of the TER [NLWDS]. It receives and stores reusable primary coolant during normal operation of Nuclear Power Plant (NPP).

The TEP [CSTS] receives demineralised water and boric acid solution (7000 mg/kg total boron concentration) via the treatment part of the TEP [CSTS] and transfers them to storage tanks for reuse. The TEP [CSTS] reduces radioactivity in the primary coolant through the degasification and the purification process.

The following sampling arrangements in the TEP [CSTS] comprise:

a) Periodic sampling for analysis through the Nuclear Sampling System (REN [NSS]) sampling line to determine if the content in the TEP [CSTS] coolant storage tanks is of suitable quality for recycling. Samples will be collected from a glove box, located in a low dose rate area, via the sampling line of storage tanks. This periodic sampling is undertaken before the liquid effluent is sent to Reactor Boron and Water Makeup System (REA [RBWMS]) storage tanks for reuse;

b) Periodic sampling, by grab sampling through the REN [NSS] sampling line, of the effluent downstream of the main process and treatment equipment such as demineraliser and coolant degasification column. Samples will be collected from a glove box, located in a low dose rate area, via the sampling line of main treatment equipment. This sampling is undertaken to evaluate the performance of the main process and treatment equipment;

c) Grab sampling through the REN [NSS] of the condensate water, downstream of the condensate degasification unit, to measure the total activity of gamma and tritium present in the condensate water. Samples will be collected from a glove box, located in a low dose rate area, via the sampling line downstream of pumps. The condensate water will be recycled if the tritium is below the control limit of the primary coolant circuit. If it is not below this limit then it will be sent to the TER [NLWDS];

d) Sampling of the sweeping gas after it has passed the storage part of the TEP [CSTS]. This sampling is undertaken downstream the sweeping gas outlet of the coolant storage tanks, through a local connection to the REN [NSS] (gaseous samples).

In-process sampling and monitoring of the liquid effluent is also arranged in the SEL [LWDS (CI)] upstream systems as shown in F-5.5-8. This figure also illustrates the sampling and monitoring related to the APG [SGBS].

APG [SGBS]

The APG [SGBS] can treat and transfer blowdown water from steam generator to the Condensate Extraction System (CEX [CES]) or the SEL [LWDS (CI)]. The sampling arrangements in the APG [SGBS] comprise:

a) Sampling of blowdown water to analyse the water quality from steam generators. The REN [NSS] extracts blowdown water continuously from the individual blowdown lines outside the steam generator, upstream of the treatment equipment. The activity concentration of blowdown water sample is measured continuously by the online KRT [PRMS] monitors, which are used to identify or verify leakage of steam generators. Once the activity concentration of blowdown water exceeds the KRT [PRMS] threshold, the blowdown is isolated manually by the operator. If the blowdown water cannot be recycled, it can be discharged to the TER [NLWDS]. If the blowdown water quality is sufficient for recycling, it is recycled to the CEX [CES]. The sample from the REN [NSS] is stored in the sample recovery tank, and then returned to the APG [SGBS] upstream of the treatment unit through the sample recovery pump if the sample is not polluted;

b) Manually sampling of the blowdown water from the steam generator, for chemical analysis to control the water chemistry condition of the steam generators. The effluents downstream and upstream of the main process equipment are manually sampled for chemical analysis to determine which system (the CEX [CES] or the SEL [LWDS (CI)]) the treated blowdown water shall be sent to. If the quality of the blowdown water meets the requirements for recycling, it is sent to CEX [CES]. If it does not meet these requirements, it is discharged to the SEL [LWDS (CI)];

c) To reduce the amount of liquid waste, the samples not polluted by chemicals or radioactivity are recycled. The samples from the main sampling circuit, the radioactivity measurement instrument, and the conductivity meter described above can be recycled and stored in the REN [NSS] sample recovery tank. The samples are returned to the APG [SGBS] upstream of the treatment unit through the sample recovery pump.

In-process sampling and monitoring arrangements in the APG [SGBS] system are shown in F-5.5-8. The sampling equipment is located in the secondary sampling room with low dose rate and adequate space for operation.

## 5.6 Independent Sampling

For the UK HPR1000, independent liquid and gaseous sampling arrangements (with sample points of the final discharges) for use by the EA or their representatives are included.

The use of an independent sampling system will not interrupt the operation of

continuous monitoring system or sampling of the routine discharges.

### 5.6.1 Gaseous Sampling

As described in section 5.5.2, the stack exhaust air is sampled and continuously monitored by means of redundant equipment. All sampling and monitoring equipment are shown in F-5.5-9 and the samples to be collected are listed in T-5.5-1. The sampling nozzles are located in the discharge stack, the sampling pipes are routed in the discharge stack, and the sampling and monitoring equipment both for train A and train B are installed in the same room under the discharge stack. An instrument platform outside the discharge stack will be built near sampling nozzles in order to facilitate the maintenance of the sampling nozzle and the flow rate instrumentation.

The two sets of sampling and monitoring equipment are running at all times. When needed, the sampling device can be used independently by the regulator. The regulator could select train A or train B freely. Tamper-free seals can be used on the redundant samplers to facilitate their use for witnessed sampling by the regulator.

There are also two flowmeters running all the time for each sets of the sampling and monitoring equipment.

### 5.6.2 Liquid Sampling

The sampling of liquid effluent discharges is performed periodically as the liquid radioactive waste is discharged by batch, and therefore the regulator will be able to take samples using the same samplers as those used by the operators. These samplers will comply with the relevant regulations. The sampling system shall have the ability to vary the amount of sample collected, so that the regulators can obtain the necessary amount of samples without affecting the sampling requirements for the operators.

To prevent tampering, the cabinet where the samplers are placed can be locked when sampling is unattended. If the samplers on the discharge line(s) are in maintenance condition, the discharge of liquid effluent should be stopped by operator. There are three storage tanks in the liquid waste discharge system, one is used to receive liquid wastes, one to mix or sample, and one is on backup. The liquid effluent could be store temporarily in these storage tanks.

## 5.7 Demonstration of BAT

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

The radioactivity discharged to the environment is measured and recorded. To quantify the gaseous and liquid radioactive discharges, sampling arrangements and radiation monitoring system are provided for the UK HPR1000. The sampling and monitoring of the final discharges is designed to calculate the both total radioactivity discharged to the environment to demonstrate compliance with requirements of

environmental permit (Sub-claim 4.1.EC05.1: All discharges are quantified to demonstrate compliance with permit requirements); and to detect abnormal performance in a timely manner (Sub-claim 4.1.EC05.2: Abnormal performance can be detected in a timely manner and give ability to minimise discharges).

Arguments and associated evidences to support these two claims are detailed in the following Sub-chapters.

### 5.7.1 Sub-claim 4.1.EC05.1 - All Discharges are Quantified Accurately to Demonstrate Compliance with Permit Requirements

The sampling and monitoring system for final discharges is designed to ensure that the effluents released to the environment comply with the requirements of the environmental permit. These include, but not limited to:

a) The application of BAT to demonstrate that discharges of radioactivity to the environment have been minimised;

b) Demonstration that discharge limits have not been exceeded;

c) Notifications to the EA; and

d) The provision of records and reports.

This claim is based on the arguments and associated supporting evidences which are presented in T-5.7-1.

T-5.7-1 Claim-Argument-Evidence Structure for Sub-claim 4.1.EC05.1

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|---|
| **5.7.1 Sub-claim 4.1.EC05.1: All Discharges are Quantified Accurately to Demonstrate Compliance with Permit Requirements** |
| **5.7.1.1 Argument 4.1.EC05.1-A1: All Final Radioactive Discharge Points are Identified and Adequately Sampled and Monitored** |
| 5.7.1.1.1 Evidence 4.1.EC05.1-A1-E1: Identification of Discharge Points |
| 5.7.1.1.2 Evidence 4.1.EC05.1-A1-E2: All Discharge Points are Adequately Monitored and/or Sampled |
| **5.7.1.2 Argument 4.1.EC05.1-A2: Representative Samples are Collected at Discharge Points** |
| 5.7.1.2.1 Evidence 4.1.EC05.1-A2-E1: Samples are Collected Where Effluent is Representative |
| 5.7.1.2.2 Evidence 4.1.EC05.1-A2-E2: Transmission Ratio of Sampling Tubes for Particles Satisfies the Requirement of BS ISO 2889: 2010 |
| 5.7.1.2.3 Evidence 4.1.EC05.1-A2-E3: Use of Flow Proportional Sampler |
| **5.7.1.3 Argument 4.1.EC05.1-A3: Appropriate Techniques have been Selected for Radioactive Discharges Measurement** |

| |
|---|
| 5.7.1.3.1 Evidence 4.1.EC05.1-A3-E1: Volume is Measured with Qualified Flowmeter for Liquid and Gaseous Discharges |
| 5.7.1.3.2 Evidence 4.1.EC05.1-A3-E2: Measurement of Activity for Liquid and Gaseous Discharges is Performed with Equipment that Meet the Requirements of Detection Limits in 2004/2/Euratom |
| 5.7.1.3.3 Evidence 4.1.EC05.1-A3-E3: Radioactive Characterisation has been Performed for Whole Process of Solid and Non-aqueous Liquid Wastes |
| 5.7.1.3.4 Evidence 4.1.EC05.1-A3-E4: Calibration Considerations will be Implemented for all Detectors |

5.7.1.1 Argument 4.1.EC05.1-A1: All Final Radioactive Discharge Points are Identified and Sampled and Monitored

In order to quantify the radioactivity discharged to the environment, all radioactive discharge points need to be first identified and then samples should be collected at the final discharge points for laboratory analysis or online monitors be arranged as necessary.

The design of the UK HPR1000 includes two points at which radioactive effluents are discharged into the environment. These are the discharge stack and the liquid radwaste discharge outfall. (Evidence 4.1.EC05.1-A1-E1: Identification of Discharge Points). The design includes sampling and monitoring equipment at both of these locations (Evidence 4.1.EC05.1-A1-E2: All Discharge Points are Monitored and/or Sampled).

5.7.1.1.1 Evidence 4.1.EC05.1-A1-E1: Identification of Discharge Points

For the UK HPR1000, there are two points to discharge radioactive effluents, which are the discharge stack and the liquid radioactive waste discharge outfall. The schematic view of discharge points are shown in F-5.5-1 and F-5.5-2.

An overview of gaseous streams is shown in F-5.5-1. The discharge stack receives gaseous effluent from the HVAC system lines. The overview of the liquid effluent streams is shown in F-5.5-2.

The liquid radioactive waste is discharged by two systems, the TER [NLWDS] and the SEL [LWDS (CI)]. These are connected to a single, common, final discharge line.

5.7.1.1.2 Evidence 4.1.EC05.1-A1-E2: All Discharge Points are Adequately Monitored and/or Sampled

At these final discharge points presented in 5.7.1.1.1, appropriate sampling or monitoring measures are provided to facilitate the evaluation of the total activity discharged to the environment. The location of these monitoring and sampling points is illustrated in F-5.5-4, F-5.5-5 and F-5.5-3.

For liquid discharges, final samples are collected using a flow proportional sampler

and sent to the laboratory for analysis to obtain accurate measurements of the discharged effluent characteristics. These final sampling points are located on the discharge line of the TER [NLWDS] and the SEL [LWDS (CI)], with one per line. In addition, the online KRT [RPMS] monitors are arranged to measure the activity concentration of liquid discharges by using a gamma sensitive detector for each discharge line.

For gaseous discharges, the activity concentration of air extracted from the discharge stack is measured using the online KRT [PRMS] monitors and characterised using samples collected by the KRT [PRMS] devices and sent for laboratory analysis.

5.7.1.2 Argument 4.1.EC05.1-A2: Representative Samples are Collected at Discharge Points

All samples of radioactive discharges that are collected must be representative. This is to ensure that any subsequent measurements, tests, analyses and calculations provide an accurate measurement of the radioactivity that has been discharged to the environment. The design of the UK HPR1000 includes a number of features that will ensure that the samples will be representative：

a) Samples are collected at a point where the effluent has been demonstrated to be well mixed. For gaseous discharges compliance with international standards will be demonstrated by laboratory and field tests. For liquid discharges, efficiency of mixing devices will be demonstrated during commissioning (Evidence 4.1.EC05.1-A2-E1: Samples are Collected Where Effluent is Representative);

b) A calculation report has been prepared for the Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)) together with relevant supporting documentation, *Particle Penetration Factor Report for Gaseous Effluent*, Reference [28], to demonstrate that the transmission ratio for particles will meet the requirements in BS ISO 2889: 2010 (Evidence 4.1.EC05.1-A2-E2: Transmission Ratio of Sampling Tubes for Particles Satisfies the Requirement of BS ISO 2889: 2010);

c) Samples of final liquid effluent will be collected using flow proportional samplers which will be specified by the future owner/operator (Evidence 4.1.EC05.1-A2-E3: Use of Flow Proportional Sampler).

Collectively, the above features demonstrate that representative samples of radioactive discharges will be taken. This is considered to represent BAT for this stage of the GDA.

It should also be noted that the representativeness of samples cannot be fully demonstrated at the GDA step since it is highly linked to the detailed design in site specific stage.

5.7.1.2.1 Evidence 4.1.EC05.1-A2-E1: Samples are Collected Where Effluent is Representative

Gaseous discharges

For the UK HPR1000, a shrouded single nozzle sampling probe will be used. According to BS ISO 2889: 2010, if a single nozzle probe is used, the customer must prove that the effluent is well mixed in the sampling plane. The acceptance criteria are listed below:

a) Coefficients of variation over the central 2/3 by area of the cross-section within 20 % for with an aerodynamic particle diameter of 10 μm, gaseous tracer, and gas velocity;

b) Flow angle <20° relative to the long axis of the stack and nozzle inlet;

c) The tracer gas concentration should not vary from the mean by > 30 % at any point on the measurement grid.

The above requirements will be proved through tests, including both laboratory and field testing. For the laboratory test, a proportional model will be constructed to simulate real conditions. The model will consist of a stack, structures in the stack, a mixing room, and ventilation ducts. Before the construction of the model, a software simulation has been conducted to validate the selection of the pre-selected sampling plane. Once the discharge stack of NPP is built and the ventilation systems come into operation, a field test will be executed. The flow characteristic is tested and compared with the result of the laboratory test to validate if the latter can represent real conditions. The software simulation report and laboratory test report have been prepared for the HPR1000 (FCG3) in *The CFD Analysis Report for Representative Sampling of Gaseous Effluent*, Reference [29]. This also aims to demonstrate best available techniques have been adopted to obtain representative gaseous sample.

Liquid discharges

As mentioned in section 5.5.6, the UK HPR1000 liquid discharge is a batch process. Once the level of liquid effluent in a storage tank reaches a predetermined value, the discharge pump will operate to recirculate the liquid in the tank via a recirculation line. The recirculation line and the recirculation time are designed to ensure that the liquid in the storage tank is well mixed. In addition, jet mixing devices are installed at the outlet of the recirculation line in the bottom of liquid effluent storage tank to mix the liquid. A jet mixing device efficiency test will be performed during the system commissioning to ensure that the liquid is well mixed.

The recirculation of the liquid discharge is operated via the tank recirculation line and each storage tank has its own sampling line. Before sampling, the sampling valve will be opened to drain out all of the retained liquid in the sampling line to ensure the sample represents the liquid effluent in the tank. The liquid drained out during

sampling is collected and routed back to storage tanks in the TER [NLWDS] and the SEL [LWDS (CI)]. The sample is collected with a MCERTS accredited flow proportional sampler if such equipment is available.

5.7.1.2.2 Evidence 4.1.EC05.1-A2-E2: Particle Penetration Factor through Sampling Pipe will Satisfies the Requirement of BS ISO 2889: 2010

The sampling pipe is made of stainless steel to prevent particle loss from electrostatic effects. The section out of the mixing room will be heated to avoid condensation of $I_2$ and water vapour. The sampling pipes are designed to minimise the transmission losses of particles, with the numbers of bends and horizontal sections minimised for example.

The total transmission efficiency of the sampling lines will meet the requirements of BS ISO 2889: 2010, including the requirements on sampling probes and pipes. In BS ISO 2889: 2010, the particle penetration factor is required to be > 50% for particles with an aerodynamic diameter of 10 μm. The code Depo2001a will be adopted for the calculation. A calculation report has been prepared for the HPR1000 (FCG3), which demonstrates that the transmission ratio for particles meets the above requirements, Reference [28].

5.7.1.2.3 Evidence 4.1.EC05.1-A2-E3: Use of Flow Proportional Sampler

A flow proportional sampler device is installed on each of the discharge lines (one on the TER [NLWDS] and one on the SEL [LWDS (CI)]), to sample the liquid effluents during discharge. A number of discrete samples will be taken and then mixed together to form a single composite sample. The result for composite sample will therefore be an average value for the radioactivity discharged which is representative of the whole discharge.

The specific flow proportional sampler to be used is not specified at the GDA stage and will consider relevant MCERTS requirements if available. Using a MCERTS accredited instrument gives confidence in the information collected from the device in terms of its accuracy, precision and tolerances.

5.7.1.3 Argument 4.1.EC05.1-A3: Appropriate Techniques have been Selected for Radioactive Discharges Measurement

For the quantification of liquid and gaseous discharges, once representative samples are collected, the total activity discharged to the environment will be determined. For this evaluation, the activity concentration and the volume of the discharge must be measured. The activity concentration is evaluated from the sample measurement which provides information on the activity of the sample, the sampling flow rate and the sampling time. The volume of the discharge is calculated from the discharge flow rate and the discharge time. For the solid and non-aqueous liquid wastes, the radiological inventories are established based on the different types of measurements

in the different processes.

To obtain an accurate result of the radioactivity discharged to the environment, the following measures will be implemented:

a) Continuous measurement of the flow rate with flowmeters (MCERTS accredited if such equipment is available) to allow the volume of liquid and gaseous effluent that has been discharged to be calculated (Evidence 4.1.EC05.1-A3-E1: Volume is Measured with Qualified Flowmeter for Liquid and Gaseous Discharges);

b) Measure the radionuclides with equipment that can work to the possible detection limits required in 2004/2/Euratom to determine the activity concentration of the discharges (Evidence 4.1.EC05.1-A3-E2: Measurement of Activity for Liquid and Gaseous Discharges is Performed with Equipment that Meet the Requirements of Detection Limits in 2004/2/Euratom);

c) Characterise the solid and non-aqueous liquid waste for the whole process (Evidence 4.1.EC05.1-A3-E3: Radioactive Characterisation has been Performed for Whole Process of Solid and Non-aqueous Liquid Wastes);

d) Calibrate the measurement instruments periodically to ensure that they are performing as expected (Evidence 4.1.EC05.1-A3-E4: Calibration Considerations will be Implemented for all Detectors).

Collectively, the above measures will ensure that an accurate record is made of radioactive discharges to the environment from the UK HPR1000. This is considered to represent BAT for this stage of the GDA.

5.7.1.3.1 Evidence 4.1.EC05.1-A3-E1: Volume is Measured with Qualified Flowmeter

Gaseous discharges

In the UK HPR1000, the volumetric flow rate of the gaseous effluent will be measured continuously using flowmeters (MCERTS accredited if such equipment is available). Two redundant (accredited) flowmeters, located in the stack, are used to measure the gaseous effluent flow. All the measuring results will be recorded in the main control room.

At the same time, the total discharge volume can be obtained by integration of the discharge time and the volumetric flow rate.

Liquid discharges

The volumetric flow rate of the liquid effluent will be measured continuously by flowmeters (MCERTS accredited if such equipment are available) located on the discharge pipeline of both the TER [NLWDS] and the SEL [LWDS (CI)] to ensure the accuracy of the calculated volume.

At the same time, the total discharge volume can be obtained by integration of the

discharge time and the volumetric flow rate.

5.7.1.3.2 Evidence 4.1.EC05.1-A3-E2: Measurement of Activity is Performed with Equipment that Meet the Requirements of Detection Limits in 2004/2/Euratom

Appropriate techniques and instruments will be adopted to measure the radioactivity of radionuclides or groups of radionuclides to give confidence that the required detection limits in 2004/2/Euratom can be achieved. The radionuclides to be measured and the detection limit requirements for both the gaseous and liquid discharges are listed in T-5.4-1 and T-5.4-2.

Detection limits depend on the variables of sampling flow rate, sampling time, techniques applied, the counting time, the background noise, the volume of samples and the type of detector. Some of these parameters can be adjusted to ensure that an appropriate sample can be collected meeting the required detection limits.

Since the instrument type and the detection method will not be determined during the GDA stage but during site-specific stage, it is not possible (during the GDA stage) to show that the specific detection limits can be achieved. However, investigations have been undertaken for current commercial equipment and the detection limits of equipment in existing NPPs of China General Nuclear Power Corporation (CGN) have been collected and compared.

The types of detector used in NPPs of CGN are listed in T-5.7-2. These are recognised and proven technologies largely used in worldwide NPPs.

T-5.7-2 Measurement Equipment Used in NPPs of CGN

| **Radionuclide** | | **Types of Detector** |
|---|---|---|
| Gaseous Discharges | Co-60<br>Cs-137<br>Noble gases<br>I-131 | Gamma spectroscopy with High-purity Germanium (HpGe) detectors |
| | C-14 and H-3 | Liquid scintillation detector |
| Liquid Discharges | Co-60<br>Cs-137 | Gamma spectroscopy with HpGe detectors |
| | H-3<br>C-14<br>Sr-90 | Liquid scintillation detector |

Historical data recorded from the existing Chinese NPPs of CGN is being collected and analysed. The lowest value can help demonstrate that the detection limits of the radionuclides to be measured in the UK HPR000 can be achieved. Further details are provided in the following paragraphs.

Gaseous Discharges

Co-60 and Cs-137 are measured using gamma spectroscopy. The minimum radioactive concentration measured in existing NPPs of CGN for Co-60 and Cs-137 are { } $Bq/m^3$ and { } $Bq/m^3$ respectively with a count time of 5000 seconds using HpGe detector as shown in T-5.7-3. These two values are both lower than the detection limits required in 2004/2/Euratom. Therefore, the required detection limits of Co-60 and Cs-137 can be achieved for the UK HPR1000.

T-5.7-3 Historical Measured Data of Particulates (Gaseous Discharges)

| **Radionuclide** | **Count time (s)** | **Minimum value of historical data ($Bq/m^3$)** | **Detection limit in 2004/2/Euratom（$Bq/m^3$）** |
|---|---|---|---|
| Co-60 | 5000 | { } | 1.0E-02 |
| Cs-137 | 5000 | { } | 3.0E-02 |

Noble gases are usually analysed using a HpGe detector. Analysis of historical measured data of noble gases discharges from existing NPPs is listed in T-5.7-4. The minimum value of Kr-85 measured in an existing NPP is { } $Bq/m^3$ with a count time of 5000 seconds. The information shows that the 2004/2/Euratom detection limit of Kr-85 is not achieved and the measurement of total noble gases can be measured instead of Kr-85.

T-5.7-4 Historical Measured Data of Noble Gases (Gaseous Discharges)

| **Radionuclide** | **Count time (s)** | **Minimum value of historical data ($Bq/m^3$)** | **Detection limit in 2004/2/Euratom（$Bq/m^3$）** |
|---|---|---|---|
| Kr-85 | 5000 | { } | 1.0E+04 |

For the measurement of iodine, gamma spectroscopy is usually used. An example of the minimum radioactive concentration measured in existing NPPs for I-131 is { } $Bq/m^3$ with a count time of 5000 seconds using a HpGe detector as shown in T-5.7-5, which is lower than the detection limit required in 2004/2/Euratom. Therefore, the required detection limit of I-131 can be achieved for the UK HPR1000.

T-5.7-5 Historical Measured Data of Iodine (Gaseous Discharges)

| **Radionuclide** | **Count time (s)** | **Minimum value of historical data (Bq/m$^3$)**） | **Detection limit in 2004/2/Euratom（Bq/m$^3$）** |
|---|---|---|---|
| I-131 | 5000 | { } | 2.0E-02 |

H-3 and C-14 are collected using a bubbler system and are analysed using liquid scintillation detector. An example of the minimum radioactive concentrations measured in existing NPPs for H-3 and C-14 are { } Bq/m$^3$ and { } Bq/m$^3$ with a count time of 20 minutes and 60 minutes respectively as shown in T-5.7-6. Both of these values are lower than the detection limits required in 2004/2/Euratom. Therefore, the required detection limits of H-3 and C-14 in gaseous discharge can be achieved for the UK HPR1000.

T-5.7-6 Historical Measured Data of Tritium and Carbon-14 (Gaseous Discharges)

| **Radionuclide** | **Count time (min)** | **Minimum value of historical data (Bq/m$^3$)** | **Detection limit in 2004/2/Euratom（Bq/m$^3$）** |
|---|---|---|---|
| H-3 | 20 | { } | 1E+03 |
| C-14 | 60 | { } | 1E+01 |

Alpha emitter can be measured by an alpha beta scintillation counter. An example of a detection limit of total alpha measured for environmental monitoring is { } Bq/m$^3$ with a count time of 500 minutes using a low-level background α, β measuring instrument. Information shows that the detection limit can be achieved.

Sr-90 is not measured in CGN NPPs, so there is no information on the detection limit here. Sr-90 is usually analysed using a liquid scintillation detector, and the sampling rate and sampling time can be adjusted to ensure that the lowest possible detection limits are achieved.

Liquid Discharges

Co-60 and Cs-137 are measured using HpGe detectors. The detection limits are influenced by count time, sample size, geometry and background noise as well as the size and configuration of the crystal of the HpGe detector. An example of the minimum measured value is { } Bq/m$^3$ and { } Bq/m$^3$ for Co-60 and Cs-137 respectively with a count time of 20000 seconds as shown in T-5.7-7. Therefore, a detection system meeting the required detection limits in 2004/2/Euratom can be selected for the UK HPR1000.

T-5.7-7 Historical Measured Data of Co-60 and Cs-137 (Liquid Discharges)

| **Radionuclide** | **Count time (s)** | **Minimum value of historical data (Bq/m$^3$)** | **Detection limit in 2004/2/Euratom（Bq/m$^3$）** |
|---|---|---|---|
| Co-60 | 20000 | { } | 1E+04 |
| Cs-137 | 20000 | { } | 1E+04 |

Currently H-3 and C-14 are analysed using a liquid scintillation detector. The detection limit is affected by the counting time and the type of scintillator. The minimum measured value is { } Bq/m$^3$ with a count time of 20 minutes for H-3, and { } Bq/m$^3$ with a count time of 60 minutes for C-14 as shown in T-5.7-8. Results show that the detection limits in 2004/2/Euratom can be met for the UK HPR1000.

T-5.7-8 Historical Measured Data of Tritium (Liquid Discharges)

| **Radionuclide** | **Count time (min)** | **Minimum value of historical data (Bq/m$^3$)** | **Detection limit in 2004/2/Euratom（Bq/m3）** |
|---|---|---|---|
| H-3 | 20 | { } | 1E+05 |
| C-14 | 60 | { } | --- |

For Sr-90, liquid scintillation detector is used. The minimum measured value is { } Bq/m$^3$ with a counting time of 200 minutes as shown in T-5.7-9, which shows a detection system to meet the required detection limit in 2004/2/Euratom can be selected for the UK HPR1000.

T-5.7-9 Historical Measured Data of Sr-90 (Liquid Discharges)

| **Radionuclide** | **Count time (min)** | **Minimum value of historical data (Bq/m$^3$)** | **Detection limit in 2004/2/Euratom（Bq/m$^3$）** |
|---|---|---|---|
| Sr-90 | 200 | { } | 1E+03 |

Alpha emitters can be measured by an alpha beta scintillation counter. An example of the detection limit of total alpha measured for environmental monitoring is { } Bq/m$^3$ with a counting time of 500 min using a low-level background α, β measuring instrument. Information shows that the detection limit in 2004/2/Euratom can be achieved.

The analysis of detection limits presented is based on the requirements of the

detection limits listed in 2004/2/Euratom. However, the UK HPR1000 proposed annual limits for significant radionuclides are provided in PCER Chapter 6, and the detection limit needs to be at a level where compliance with these limits can be demonstrated. The activity concentration of significant radionuclides such as H-3 and C-14 is calculated and is shown in T-5.7-10 and T-5.7-11. Information shows that the Operating Experience (OPEX) data in NPPs of CGN can readily demonstrate compliance with the proposed limits.

T-5.7-10 Estimated Activity Concentration of Gaseous Discharges (Proposed Limits)

| Radionuclides | H-3 | C-14 | Reference |
|---|---|---|---|
| Annual discharge limit (Bq) | 5.23E+12 | 1.69E+12 | PCER Chapter 6 |
| Discharge flow rate ($m^3$/h) | 3.35E+05 | 3.35E+05 | Example of reference plant |
| Sampling flow rate (L/h) | 20 | 20 | Example |
| Sampling period (h) | 168 | 336 | Example |
| Activity of sample (Bq) | 3.15E+03 | 1.59E+03 | / |
| Volume of solution (mL) | 5 | 6 | Example |
| Activity concentration of sample (Bq/$m^3$) | 1.20E+09 | 6.44E+08 | / |
| Minimum value (Bq/$m^3$) | { } | { } | OPEX |

T-5.7-11 Estimated Activity Concentration of Liquid Discharges (Proposed Limits)

| Radionuclides | H-3 | C-14 | Reference |
|---|---|---|---|
| Annual discharge limit (Bq) | 1.04E+14 | 5.90E+10 | PCER Chapter 6 |
| Discharge volume ($m^3$) | 3.50E+04 | 3.50E+04 | Example of reference plant |
| Averaged activity concentration (Bq/$m^3$) | 2.97E+09 | 1.69E+06 | / |
| Minimum value (Bq/$m^3$) | { } | { } | OPEX |

This section describes the techniques available for the measurement of activity based on the requirements of the detection limits. Detection methods are constantly evolving,

and therefore it is appropriate for the operator to define specific instrumentation during site specific stage. The operator will need to consider a range of factors including but not limited to detection limits, range, accuracy, sensitivity, reliability, availability and durability.

5.7.1.3.3 Evidence 4.1.EC05.1-A3-E3: Radioactive Characterisation has been Performed for Whole Process of Solid and Non-aqueous Liquid Wastes

As described in section 5.5.4, the sampling and monitoring arrangements for solid and non-aqueous liquid waste are undertaken in different processes for different requirements in place:

a) For each of the wastes generated, sampling and/or monitoring is performed to determine the category of the radioactive waste and to select the optimal treatment process and disposal routes;

b) Before and during processing, sampling and/or monitoring is performed to ensure that the waste to be packaged and the resulting waste packages comply with relevant criteria such as the waste acceptance criteria of off-site treatment or disposal facilities;

c) Before, and during storage, the monitoring of solid waste packages and non-aqueous liquid waste packages is undertaken to confirm and record their radiological inventories so as to ensure the waste package is stored in the relevant location; that the performance integrity (retrievability and disposability) of the waste packages is maintained; and that the risk of radioactive contamination diffusion, and other risks are reduced. Accurate radiological inventories are also required to ensure that the site understands the radioactive waste inventory on-site at all time;

d) Before disposal or off-site treatment, monitoring is undertaken to assess whether the waste packages meet the requirements of transportation, off-site treatment and final disposal.

Different types of measurements are selected according to the monitoring requirements. Details are presented in section 5.5.4.

5.7.1.3.4 Evidence 4.1.EC05.1-A3-E4: Calibration Considerations will be Implemented for all Detectors

In order to ensure the accuracy of the measurements taken, periodic calibration will be needed for all type of detectors. Calibration procedures vary for different types of detectors. The suppliers of the detectors will provide calibration methods (at site-specific stage) and corresponding tools for their products.

### 5.7.2 Sub-claim 4.1.EC05.2 - Abnormal Performance Can be Detected in a Timely Manner to Give Ability to Minimise Discharges

This claim demonstrates that abnormal performance can be detected by the radiation monitoring and sampling in a timely manner and that deviations from normal values can be mitigated by appropriate measures that will minimise radioactive discharge. In this claim, information is focused on the radiation monitoring and sampling related to the final discharges. Additionally, many other parameters to determine the performance of the plant are monitored on the UK HPR1000 design, such as the monitoring of temperature, humidity, pressure, and conductivity. Information related to these parameters and the contribution that they make to optimise the environmental performance of the plant is described in PCER Chapter 3.

The arguments and evidences presented to underpin this claim are presented in T-5.7-12.

T-5.7-12 Claim-Argument-Evidence Structure for 4.1.EC05.2

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| **5.7.2 4.1.EC05.2: Abnormal Performance Can be Detected in a Timely Manner to Give Ability to Minimise Discharges** |
| **5.7.2.1 Argument 4.1.EC05.2-A1: Location Selection of Monitoring and Sampling Can Facilitate Identification of the Source Position of Abnormal Performance and Provide Information of System Performance** |
| 5.7.2.1.1 Evidence 4.1.EC05.2-A1-E1: Final Discharges are Continuously Monitored at the Discharge Point |
| 5.7.2.1.2 Evidence 4.1.EC05.2-A1-E2: Arrangements of In-process Monitoring and Sampling Can Detect the Abnormal Performance Prior to Final Discharge Points |
| **5.7.2.2 Argument 4.1.EC05.2-A2: Appropriate Methods are Used to for KRT [PRMS] Monitors Satisfy the Measuring Objectives** |
| 5.7.2.2.1 Evidence 4.1.EC05.2-A2-E1: Measuring Method for Final Discharges |
| 5.7.2.2.2 Evidence 4.1.EC05.2-A2-E2: Measuring Method for In-process Effluent |
| **5.7.2.3 Argument 4.1.EC05.2-A3: Appropriate Alarm Thresholds and Alarm Actions are Set to Detect and Mitigate the Deviations From Normal State at an Earlier Stage** |
| 5.7.2.3.1 Evidence 4.1.EC05.2-A3-E1: Final Sampling and Monitoring Alarm Arrangements |
| 5.7.2.3.2 Evidence 4.1.EC05.2-A3-E2: In-process Sampling and Monitoring Alarm Arrangements |

5.7.2.1 Argument 4.1.EC05.2-A1: Location Selection of Monitoring and Sampling Facilitate Identification of the Source Position of Abnormal Performance and Provide Information of System Performance

A range of sampling and monitoring equipment is provided to demonstrate that the plant is performing as expected and to provide plant operators with relevant information. In particular, this equipment must alert operators of any deviations in plant performance that could challenge compliance with authorised discharge limits or challenge the application of BAT.

The location of sampling and monitoring equipment takes into consideration the functions of the system and the characteristics of the radioactive waste with which they are associated. This allows the sampling and monitoring systems to provide information on the source of any deviation in plant performance which, in turn, allows time for further corrective actions as described in Argument 4.1.EC05.2-A3: Appropriate Alarm Thresholds and Alarm Actions are Set to Detect and Mitigate the Deviation from Normal State at an Earlier Stage.

At the final discharge points, online monitors are provided to continuously monitor the activity in the discharge and the discharge flow rate. The information is transferred to the control room (Evidence 4.1.EC05.2-A1-E1: Final Discharges are Continuously Monitored at the Discharge Point).

In-process monitoring is arranged for all of the systems that feed into the discharge stack. This allows the source of elevated levels of radioactivity to be identified. Sampling and analysis of the inputs of the final liquid discharge systems are undertaken to determine plant performance and to demonstrate that effluent is suitable for discharge into the environment (Evidence 4.1.EC05.2-A1-E2: Arrangements of In-process Monitoring and Sampling Can Detect the Abnormal Performance Prior to Final Discharge Points).

The combination of in-process monitoring and the monitoring of final discharges demonstrates that plant deviations will be detected in a timely manner and be available to plant operators so that sufficient time is available to determine what actions to be taken. This is considered to represent BAT for this stage of the GDA.

5.7.2.1.1 Evidence 4.1.EC05.2-A1-E1: Final Discharges are Continuously Monitored at the Discharge Point

Gaseous discharges

At the discharge stack, the gaseous radioactive waste is continuously discharged to the environment. As the final process, the online KRT [PRMS] detectors continuously measure the air extracted from the discharge stack and the real time data will be sent to the operating personnel in the main control room. The discharge flow rate is also continuously monitored. The measurement data is recorded to provide trends, which

can help to identify any deviation from the normal state.

Liquid discharges

There are two final discharge systems, the TER [NLWDS] and the SEL [LWDS (CI)], which are connected to one common final discharge line. They are monitored and sampled separately. Each discharge system is provided with an online KRT [PRMS] monitor and a flowmeter (MCERTS accredited if such equipment is available). These are located on the discharge line as shown in F-5.5-5 to continuously monitor the activity concentration and flow rate during the discharge. Samples are collected by using the flow proportional sampler. This arrangement allows any elevated activity concentrations to be identified in a timely manner.

5.7.2.1.2 Evidence 4.1.EC05.2-A1-E2: Arrangements of In-process Monitoring and Sampling Can Detect the Abnormal Performance Prior to Final Discharge Points

Prior to the final discharge, in-process monitoring and sampling arrangements are provided to monitor and detect the abnormal performance in appropriate locations. As described in preceding sections, the TEU [LWTS], the TEP [CSTS] and the APG [SGBS] are the systems that transfer effluent to the TER [NLWDS] and the SEL [LWDS (CI)] for liquid discharge, and the DWN [NABVS], the TEG [GWTS] and the CVI [CVS] for gaseous discharges. The sampling and monitoring locations and functions in these systems are presented in T-5.7-13 and T-5.7-14.

All of the monitoring or sampling points selected in these process systems are located so as to facilitate the identification of the position where any abnormal increase of radioactivity occurs. For example, all the gaseous inputs to the discharge stack are measured separately before entering into the discharge stack, thereby enabling the position of an increase in activity to be determined. For the liquid effluent, the liquid abatement systems are monitored or sampled separately; allowing the origin of elevated levels of radioactivity to be also determined.

T-5.7-13 Monitoring and Sampling Arrangement of In-process Liquid Effluent

| Process System | Monitoring/Sampling Location | Function |
|---|---|---|
| TEU [LWTS] | Grab sampling: Recirculation line of storage tanks | To select the appropriate treatment process |
| | Grab sampling: Downstream of each demineraliser, recirculation pump and distillate pump | To evaluate the performance of equipment |
| | Grab sampling: Recirculation line of monitoring tanks | To analyse and confirm that the properties of the processed liquid satisfy the discharge requirement |

| Process System | Monitoring/Sampling Location | Function |
|---|---|---|
| TEP [CSTS] | Periodic sampling: coolant storage tanks | To characterise the coolant to determine if it is of suitable quality for recycling |
| | Periodic sampling: downstream of the demineraliser and coolant degasification column | To evaluate the performance of the main process and treatment equipment. |
| | Periodic sampling: downstream of the condensate degasification unit | To measure the total activity of gamma and tritium radioactivity of the condensate water before it is discharged to the TER [NLWDS] |
| APG [SGBS] | KRT [PRMS] monitors: water sampling from the blowdown pipeline of each steam generator via the REN [NSS] | To provide information on the heat transfer tube leakage of the steam generator. |
| | Grab sampling: downstream and upstream of the main process equipment | To analyse the chemical properties to determine the discharge route |

T-5.7-14 Monitoring and Sampling Arrangement of In-process Gaseous Effluent

| Process System | Monitoring/Sampling Location | Function |
|---|---|---|
| TEG [GWTS] | KRT [PRMS] monitor at the recirculation flushing line | To measure the radioactivity level entering the delay bed |
| | KRT [PRMS] monitor downstream of the delay bed. | To measure the noble gases activity discharged to DWN [NABVS] |
| | Grab sampling: upstream and downstream of the delay bed. | To monitor the performance of the delay bed. |
| CVI [CVS] | KRT [PRMS] monitor on the discharge line of the CVI [CVS] | To measure the activity concentration of the |

| Process System | Monitoring/Sampling Location | Function |
|---|---|---|
| | | non-condensable air;<br>To detect the steam generator leakage. |
| DWN [NABVS] | KRT [PRMS] monitors on the pipelines of the ventilation systems | To measure the activity of the exhaust air from the NI ventilation systems. |
| Others | Area KRT [PRMS] monitors located within the controlled areas | To indicate the elevated activity level in those controlled areas. |

5.7.2.2 Argument 4.1.EC05.2-A2: Appropriate Methods are Used for KRT [PRMS] Monitors to Satisfy the Measuring Objectives

Radiation monitoring is provided in the design of the UK HPR1000 to provide plant operators with real-time information on the performance of the plant and the amount of radioactivity that is being discharged to the environment.

For the KRT [PRMS] monitoring, three types of measuring methods are applied including in-line, on-line and off-line measurements:

a) In-line measurements: measurements with monitors located inside the fluid pipe or the ventilation pipe/duct;

b) On-line measurements: measurements with monitors located outside the fluid pipe or the ventilation pipe/duct;

c) Off-line measurements: measurements where the fluid is extracted to an appropriate location (for example, with low background noise) by a sampling line and then continuously measured by monitors.

Appropriate measuring and detection methods are selected to monitor the radioactivity of final discharges, taking account of the purpose of measurement, what is to be measured, the layout of the equipment where the measurement is to be undertaken and human factors (Evidence 4.1.EC05.2-A2-E1: Measuring Method for Final Discharges) and in-process effluent (Evidence 4.1.EC05.2-A2-E2: Measuring Method for In-process Effluent).

5.7.2.2.1 Evidence 4.1.EC05.2-A2-E1: Measuring Method for Final Discharges

At the final gaseous discharge point, the aerosol, iodine and noble gases levels are measured using integrated equipment. An off-line measurement approach is applied, with the gaseous sample drawn via a sample pump, from the discharge stack, and

directed into sampling/detection units. In these units, the aerosol is trapped on a filter, the iodine is trapped on an activated charcoal unit, and the noble gases are collected in a shielded vessel. Measurement range for each detection system will be determined based on the discharge source term.

In-line measuring methods are used for the liquid discharge with detectors inside the discharge lines of the TER [NLWDS] and the SEL [LWDS (CI)] to measure the activity concentration during the discharge. Lead shielding is provided to minimise the interference by THE background environmental gamma radiation. An appropriate measuring range is set based on the discharge source term and OPEX taken from CGN's NPPs.

5.7.2.2.2 Evidence 4.1.EC05.2-A2-E2: Measuring Method for In-process Effluent

As described in preceding sub-chapters, the TEU [LWTS], the TEP [CSTS] and APG [SGBS] are the upstream systems for liquid discharges, and the DWN [NABVS], the TEG [GWTS] and the CVI [CVS] for gaseous discharges. In-process monitoring and sampling arrangements are provided to monitor and detect the abnormal performance.

For liquid effluent monitoring, samples in the TEU [LWTS] and the TEP [CSTS] are collected for laboratory analysis before being discharged to the TER [NLWDS]. The KRT [PRMS] monitor is provided to monitor for leaks of steam generator in the APG [SGBS].

Since the activity concentration of gaseous effluents is usually low, off-line measuring methods are adopted for monitoring the exhaust air discharged from the DWN [NABVS] and the TEG [GWTS]. This should increase the sensitivity of the monitoring. For monitoring of the CVI [CVS] exhaust air, on-line measurement methods are used to measure the radioactivity in the discharge pipe line to indicate steam generator leakages.

Radioactivity monitoring with continuously operating instrumentation shall be supplemented by laboratory evaluation of samples taken intermittently. The sampling cycles are stipulated in the operating manual.

The measuring method is summarised in T-5.7-15 and T-5.7-16.

T-5.7-15 Summary of Measuring Method (Liquid Effluents)

| Process System | Monitoring/Sampling type | Measuring Method |
|---|---|---|
| TEU [LWTS] | Grab sampling | Sampling and analysis in the laboratory |

| Process System | Monitoring/Sampling type | Measuring Method |
|---|---|---|
| TEP [CSTS] | Grab sampling | Sampling and analysis in the laboratory |
| APG [SGBS] | KRT [PRMS] monitors: water sampling from the blowdown pipeline of each steam generator<br>Grab sampling | Off-line continuous monitoring<br>Sampling and analysis in the laboratory |

T-5.7-16 Summary of Measuring Method (Gaseous Effluents)

| Process system | Monitoring/Sampling type | Measuring Method |
|---|---|---|
| TEG [GWTS] | KRT [PRMS] monitors at the recirculation flushing line;<br>KRT [PRMS] monitors downstream of the delay bed. | On-line continuous monitoring<br>Off-line continuous monitoring |
| | Grab sampling: upstream and downstream of the delay bed. | Sampling and analysis in the laboratory |
| CVI [CVS] | KRT [PRMS] monitor: on the discharge line of CVI [CVS] | On-line continuous monitoring |
| DWN [NABVS] | KRT [PRMS] monitors: on the pipelines of the ventilation systems | Off-line continuous monitoring |

5.7.2.3 Argument 4.1.EC05.2-A3: Appropriate Alarm Thresholds and Alarm Actions are Set to Detect and Mitigate the Deviation from Normal State at an Earlier Stage

The operating philosophy for the UK HPR1000 sets the alarm levels, alarm thresholds and associated responses for the parameters that are considered important to plant performance. They allow abnormal performance to be brought to the attention of the plant operators so that appropriate remedial action can be instigated.

Alarm thresholds are determined for the KRT [PRMS] monitors with the associated actions that are to be undertaken in the event that the threshold is exceeded. Appropriate alarm arrangements are considered for the KRT [PRMS] monitors for the final discharges which, firstly, provide operators with an early warning of an increase

in activity and, secondly, notify that discharges are exceeding the operating set threshold (Evidence 4.1.EC05.2-A3-E1: Final Sampling and Monitoring Alarm Arrangements and Associated Actions). Alarm arrangements are also considered for the in-process monitoring (Evidence 4.1.EC05.2-A3-E2: In-process Sampling and Monitoring Alarm Arrangements).

5.7.2.3.1 Evidence 4.1.EC05.2-A3-E1: Final Sampling and Monitoring Alarm Arrangements and Associated Actions

Appropriate alarm thresholds and alarm actions are considered to identify the deviation at an early stage and to minimise the discharges.

a) For online gaseous discharge monitoring, two levels of alarm thresholds are set for each monitoring channel, with the alarm thresholds derived and determined from the proposed discharge limits:

    1) A level 1 alarm is used to provide an early warning that the gaseous activity concentration is increasing and there is a risk of a discharge occurring with an activity higher than the operating set threshold. In this case, operators in the main control room need to check the measurement results of the redundant monitoring channels to verify the information and need to inform the local workers to collect samples for laboratory analysis. The upstream monitoring channels also need to be checked. In addition, inspection operators need to be informed to search the leak point (if any) so that corrective actions can be taken as early as possible.

    2) A level 2 alarm is used to warn that there is a discharge with an activity higher than the operating set threshold and corrective actions need to be taken quickly to minimise the discharge.

b) For online liquid discharge monitoring, the same principle of alarm thresholds and alarm levels is applied. Two levels of alarm are provided:

    1) A level 1 alarm is to warn the operator that there is a risk of a discharge with a high activity concentration and that operators need to keep paying attention to the measurement results from liquid discharge monitoring channels and inform operators to collect samples for laboratory analysis.

    2) A level 2 alarm is to inform the operators that the activity concentration is higher than the authorised threshold and that the permit limit might be challenged and corrective actions need to be taken, including manual operation such as transfer to the TEU [LWTS] for re-treatment. An action to isolate the discharge valves is triggered automatically when the level 2 alarm threshold is exceeded or a failure of monitor and/or flow proportional sampler is detected. This arrangement helps control and minimise liquid discharges.

5.7.2.3.2 Evidence 4.1.EC05.2-A3-E2: In-process Sampling and Monitoring Alarm Arrangements

The in-process sampling and monitoring alarm arrangements are summarised in T-5.7-17.

T-5.7-17 Alarm Arrangements for In-process Effluents

| Process System | Alarm Level | Alarm Actions |
|---|---|---|
| APG [SGBS] | Two alarm levels to detect the steam generator leakages;<br>Alarm thresholds are set based on the leakage rate of steam generator. | Automatic actions: None;<br>Others: Actions will be taken by the operating personnel according to the reactor state and operating procedures will be applied. |
| CVI [CVS] | One alarm level to detect the steam generator leakage;<br>Alarm threshold is consistent with that of the APG [SGBS] monitor. | Automatic actions: None;<br>Others: Actions will be taken by the operating personnel according to the reactor state and operating procedures will be applied. |
| TEG [GWTS] | One alarm level is set for the KRT [PRMS] monitor downstream the delay bed;<br>Alarm threshold is set based on the proposed discharge limits and/or system performance. | Automatic actions: None;<br>Others: Samples might be collected for laboratory analysis, and corrective action will be taken if necessary. |
| Airborne radioactivity in ventilation systems | Alarm thresholds are set based on the internal radiation protection for operators (air concentration) | Automatic actions: Switching to iodine filter train to minimise the air discharged to the discharge stack automatically; visual and audible alarms will be generated to warn operators;<br>Others: Corrective action to find the origin of radioactivity will be taken. |

## 5.8 Conclusions

Information on radioactive sampling and monitoring arrangements of discharges and the disposals of radioactive wastes is developed in this chapter to respond to the requirement in P&ID item 6, Table 1. During the GDA stage, it is not yet possible to provide details of the monitoring and sampling design, so the focus of this chapter is on the overview of monitoring and sampling arrangement and techniques.

The sampling and monitoring arrangements of final discharges of liquid and gaseous wastes are presented in section 5.5.3 and section 5.5.2 respectively. The arrangements for the discharge related in-process sampling and monitoring of liquid and gaseous wastes are presented in section 5.5.6 and section 5.5.5. The description of the sampling and monitoring for solid and non-aqueous liquid wastes is developed and presented in section 5.5.4 according to the design of solid waste treatment system and the integrated waste strategy.

This chapter also includes the lists of radionuclides to be measured for the UK HPR1000 for both liquid and gaseous discharges. The demonstration of the compliance of the radionuclides with the required detection limits in 2004/2/Euratom is also presented.

A section of the BAT demonstration for the UK HPR1000 is presented in Sub-chapter 5.7, showing that the techniques and arrangements of sampling and monitoring to quantify the gaseous and liquid radioactive discharge are applying best available techniques.

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