

## Generic design assessment

# UK EPR™ nuclear power plant design by AREVA NP SAS and Electricité de France SA

**Final assessment report**

**Gaseous radioactive waste  
disposal and limits**



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**Published by:**

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[www.environment-agency.gov.uk](http://www.environment-agency.gov.uk)

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### UK EPR™ nuclear power plant design by Electricité de France SA and AREVA NP SAS

#### Final assessment report: Gaseous radioactive waste disposal and limits

<b>Protective status</b>	This document contains no sensitive nuclear information or commercially confidential information.
<b>Process and Information Document<sup>1</sup></b>	<p>The following sections of Table 1 in our Process and Information document are relevant to this assessment:</p> <p>1.5 – show that the best available techniques will be used to minimise the waste discharged.</p> <p>2.1 – describe how gaseous waste will arise, be managed and disposed of.</p> <p>2.2 – design basis estimates for monthly discharges of gaseous waste.</p> <p>2.3 – proposed annual for gaseous discharges.</p>
<b>Radioactive Substances Regulation Environmental Principles<sup>2</sup></b>	<p>The following principles are relevant to this assessment:</p> <p>RSMDP3 - Use of BAT to minimise waste</p> <p>RSMDP12 – Limits and levels on discharges</p>
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1. Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs, Environment Agency, Jan 2007.

<http://publications.environment-agency.gov.uk/pdf/GEHO0107BLTN-e-e.pdf>

2. Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation - Environmental Principles (REPs), 2010.

<http://publications.environment-agency.gov.uk/pdf/GEHO0709BQSB-e-e.pdf>

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## Summary

- 1 This report presents the findings of our assessment of gaseous radioactive waste disposals from the UK EPR™ based on information submitted by EDF and AREVA in their Pre-Construction Environmental Report (PCER) and supporting documents. We compare discharges with other comparable stations across the world and set out our proposed annual disposal limits and quarterly notification levels (QNL).
- 2 **Our conclusions remain unchanged since our consultation.**
- 3 **We conclude that the UK EPR utilises the best available techniques (BAT) to minimise discharges of gaseous radioactive waste:**
- a) **during routine operations (subject to assessment finding UK EPR-AF07) and maintenance;**
- b) **from anticipated operational events.**
- 4 **We conclude that the gaseous discharges from the UK EPR should not exceed those of comparable power stations across the world.**
- 5 **We conclude that any operational, single UK EPR unit should comply with the limits and levels set out below for the disposal of gaseous radioactive waste to air. The limits and levels will be the starting point for any site-specific permit, but will be reviewed as part of the site permitting process based on any additional information provided by a future UK EPR operator. The limits would also be reviewed periodically thereafter, as data becomes available from operational UK EPR reactors.**
- 6 **Note that the base case discharges for the UK EPR do not include any associated waste and spent fuel storage facilities, our limits do not include any allowance for possible gaseous disposals from these facilities.**

Radionuclides or group of radionuclides	Proposed Annual limit GBq	Proposed Quarterly notification level GBq
Tritium	3000	200
Carbon-14	700	100
Noble gases	22500	2250
Iodine-131	0.4	0.04
All other radionuclides (excepting tritium, carbon-14, iodine radionuclides and noble gases)	0.05	0.027

- 7 We conclude that the UK EPR stack provides adequate dispersion under GDA generic site conditions. However dispersion is very location specific and will need to be demonstrated as adequate by modelling for each specific site.
- 8 **As part of our assessment we identified the following assessment finding:**
- a) **Future operators shall, before the commissioning phase, provide an assessment to demonstrate that proposed operational controls on the fuel pool are BAT to minimise the discharge of tritium to air. (UK EPR-AF07)**
- 9 Our findings on the wider environmental impacts and waste management arrangements for the UK EPR reactor may be found in our Decision Document (Environment Agency, 2011a).

## 1 Introduction

10 We originally published this report in June 2010 to support our GDA consultation on the UK EPR design. The consultation was on our preliminary conclusions. It began on 28 June 2010 and closed on 18 October 2010.

11 We received additional information from EDF and AREVA after June 2010 and also undertook additional assessment in response to consultation responses. This report is an update of our original report covering assessment undertaken between June 2010 and the end of March 2011 when EDF and AREVA published an update of their submission. Where any paragraph has been added or substantially revised it is in a blue font.

12 We do not specifically deal with consultation responses in this report, they are covered in detail in the Decision Document (Environment Agency, 2011a). However, where a response prompted additional assessment by us this is referenced, the key to GDA reference numbers is in Annex 7 of the Decision Document. The conclusions in this report have been made after consideration of all relevant responses to our consultation.

13 In addition to using BAT to prevent and, where that is not practicable, minimise the creation of radioactive waste (as discussed in our report EAGDAR EPR-03, see Environment Agency, 2011b), we also expect new nuclear power plant to use BAT to minimise the impact of discharges of radioactive waste to the environment.

14 This report assesses the gaseous radioactive waste created and whether the UK EPR uses BAT to minimise the impact of its discharge. We compare discharges with other comparable stations across the world and propose disposal limits and notification levels for those discharges.

15 We set out in our Process and Information Document (Environment Agency, 2007) (P&ID) the requirements for a Requesting Party to provide information that:

- a) shows BAT will be used to minimise the discharge and disposal of gaseous radioactive wastes (reference 1.5);
- b) describes sources of radioactivity and matters which affect gaseous wastes arising (reference 2.1);
- c) gives design basis estimates for monthly discharges of gaseous radioactive waste (reference 2.2); and
- d) gives their proposed annual limits with derivation for gaseous radioactive waste (reference 2.3).

### 1.1 BAT to minimise discharges of gaseous radioactive waste

16 Statutory Guidance (DECC, 2009) to us in 2009 reinforced the requirement to use BAT, paragraph 23:

*“In relation to any designs for new nuclear power stations, the Environment Agency should ensure that BAT is applied so that the design is capable of meeting high environmental standards. This requirement should be applied at an early stage so that the most modern or best available technology can be incorporated into the design of the stations, where this would ensure improved standards. The application of BAT should ensure that radioactive wastes and discharges from any new nuclear power stations in England and Wales are minimised and do not exceed those of comparable stations across the world.”*

17 We published our Radioactive Substances Regulation Environmental Principles (REPs) in August 2009 (now RGN RSR 1 (Environment Agency 2010a)) and principle RSMDP3 (Use of BAT to minimise waste) states that:

*“The best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity.”*

- 18 The methodology for identifying BAT is given in principle RSMDP4 and the application of BAT is described in principle RSMDP6. We also published in 2010 our guidance ‘RSR: Principles of optimisation in the management and disposal of radioactive waste’ (Environment Agency, 2010b). The guidance initially says:
- ‘BAT are the means an operator uses in the operation of a facility to deliver an optimised outcome, ie to reduce exposures to ALARA’ [ALARA: as low as reasonably achievable, economic and social factors being taken into consideration].*
- 19 BAT replaces, and is expected to provide the same level of environment protection as, the previously used concepts of best practicable environmental option (BPEO) and best practicable means (BPM). BAT includes an ‘*economic feasibility*’ element. [Clarification prompted by respondent GDA126]
- 20 We keep BAT under consideration and review permits regularly to see if improvements are needed to reflect developments and improvements, for example in plant, techniques or operator practice. Our permits include conditions requiring the use of BAT and BAT requires that operators continually assess whether more can be done to reduce discharges. [Clarification prompted by respondent GDA38]
- 21 In this report we assess the techniques EDF and AREVA use in the UK EPR to minimise the discharge and impact of gaseous radioactive wastes and present our conclusions on whether BAT is demonstrated.
- 22 EDF and AREVA provided their submission to GDA in August 2007. We carried out our initial assessment and concluded we needed additional information. We raised a Regulatory Issue on EDF and AREVA in February 2008 setting out the further information that we needed. In particular we believed P&ID reference 1.5 had not been addressed by the submission and required “*a formal BAT assessment for each significant waste stream*”.
- 23 EDF and AREVA completely revised their submission during 2008 and provided a Pre-Construction Environmental Report (PCER) with supporting documents.
- 24 We assessed information contained in the PCER but found that while much improved from the original submission it still lacked the detail we require to demonstrate BAT is used. We raised two Regulatory Observations (ROs) on EDF and AREVA in May and June 2009 that had actions to provide:
- a) a detailed BAT assessment for carbon-14 to demonstrate that its discharges had been minimised, we specifically addressed carbon-14 as its impact was the highest of the discharged radionuclides;
  - b) more general BAT assessments to show the significance of individual radionuclide arisings and that significant arisings had been minimised.
- 25 We raised 33 Technical Queries (TQs) on EDF and AREVA during our assessment. Three were relevant to this report:
- a) TQ-EPR-183: Fuel management regimes and their impact on proposed liquid and gaseous radioactive waste discharges;
  - b) TQ-EPR-184: Coolant degasification system;
  - c) TQ-EPR-185: Gaseous radioactive waste abatement systems.

26 We also liaised with the Office for Nuclear Regulation<sup>1</sup> (ONR) on matters of joint  
interest and used their Step 3 and Step 4 reports to inform our assessment.

27 EDF and AREVA responded to all the ROs and TQs. They reviewed and updated  
the PCER in March 2010 to include all the relevant information provided by the ROs  
and TQs up until then. This version of the PCER was referenced by our  
Consultation Document and publicly available on the UK EPR website.

28 Additional information on some topics was submitted by EDF and AREVA after  
March 2010. EDF and AREVA reviewed and updated the PCER to include all  
submitted information in March 2011. This report only uses and refers to the  
information contained in the updated PCER and its supporting documents, publicly  
available on the UK EPR website (<http://www.epr-reactor.co.uk>).

**1.2 Comparison of discharges with other stations**

29 We commissioned a study to help us compare discharges from designs put forward  
for GDA with currently operating nuclear power plant. Our Science Report  
SC070015/SR1 “*Study of historic nuclear reactor discharge data*” was published in  
September 2009. We used data from this report and our own sources to establish  
annual discharge ranges for significant radionuclides for “*comparable stations  
across the world*”, see Annex 4 of our Decision Document (Environment Agency,  
2011a).

30 This report compares the predicted gaseous discharges from the UK EPR with the  
ranges quoted in Annex 4 of the Decision Document.

Radionuclides or group of radionuclides	UK EPR expected annual discharge <sup>1</sup>	UK EPR normalised to 1000 MWe	Range for 1000 MWe station
Tritium GBq	500	290	100 - 3600
Carbon-14 GBq	350	203	40 - 530
Noble gases GBq	800	460	100 - 10000
Iodine radionuclides MBq	50	29	<1 - 2000
Other radionuclides not specifically limited MBq	4	2.3	<1 - 1000

<sup>1</sup> taken as the EDF and AREVA ‘*Annual expected performance excluding contingency*’ (PCERsc3.3 Table 4).

31 The Committee on Medical Aspects of Radiation in the Environment (COMARE)  
(GDA129) suggested that as ‘*part of a new generation of plants, it might be  
expected that discharges would be lower than existing facilities, rather than ‘within  
the range of historic discharges’ which seems to be the criterion being applied by  
EA*’.

32 We discuss the data we used to confirm discharges were comparable to current  
power stations in the Decision Document, Annex 4. We had difficulty that data was  
very variable and affected by matters such as shutdowns for periods that were not

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<sup>1</sup> The Office for Nuclear Regulation (ONR) was created on 1st April 2011 as an Agency of the Health and Safety Executive (HSE). It was formed from HSE’s Nuclear Directorate and has the same role. In this report we therefore generally use the term “ONR”, except where we refer back to documents or actions that originated when it was still HSE’s Nuclear Directorate.



known. Also the data for the UK EPR are based on predictions as no EPR is yet running. Therefore attempting comparison to show lower discharges for the UK EPR was not possible. We have indicated throughout this document areas where the UK EPR has been improved and discharge reductions are expected.

### 1.3 Discharge limits and levels

#### 1.3.1 Radionuclides on which limits should be set

33 We recommended in the P&ID that RPs should take account of our Science Report SC010034/SR "*Development of Guidance on setting limits on discharges to the Environment from nuclear sites*" (Environment Agency, 2005). The report sets out that limits should be set on radionuclides and / or groups of radionuclides which:

- a) are significant in terms of radiological impact for humans and non human species, including radionuclides that may be taken up in food;
- b) are significant in terms of the quantity of radioactivity discharges, whether or not they are significant for radiological impact;
- c) have long radioactive half-lives, that may persist and / or accumulate in the environment and that may contribute significantly to collective dose;
- d) are good indicators of plant performance and process control; or
- e) provide for effective regulatory control and enforcement.

This advice from the report was essentially confirmed in the *Considerations* section of RSMDP12 in our REPs.

34 In addition our Considerations document (Environment Agency, 2009) recommends the following criteria for identifying radionuclides or groups of radionuclides for which to set plant limits:

- a) Critical group dose from the established worst case plant discharges (EWCPD) is greater than 1  $\mu$ Sv per year;
- b) Collective dose from the EWCPD is greater than 0.1 manSv;
- c) The EWCPD exceeds 1 TBq per year;
- d) Discharges of the radionuclide are a good indicator of plant performance or process control, or limits are otherwise felt to be necessary for effective regulatory control and enforcement.

35 We used the above advice and criteria to determine appropriate radionuclides and groups of radionuclides on which to set limits.

#### 1.3.2 Time basis of limits

36 We decided that the most appropriate limit basis was that of a rolling 12 month period. This provides an element of flexibility for the site operator with respect to normal fluctuation in discharges on a month by month basis whilst exerting a smoothing effect. This encourages operators to ensure that discharges are made, wherever possible, at relatively consistent levels and to avoid short term elevations in the amount of radioactivity discharged which may increase the impact on humans or non-human species.

37 Discharge limits set on a rolling 12 month basis also allow derivation of information about discharges in any calendar year and such information is used to assess impact in terms of dose which is generally expressed in terms of dose in a calendar year. Additionally discharge limits set on a 12 month rolling basis allow reporting on

annual discharges required under such things as the OSPAR Convention<sup>2</sup> and in UK publications such as the annual publication on Radioactivity in Food and the Environment (e.g. Environment Agency *et al* 2009).

38 We discarded the concept of discharge limits set in terms of activity discharge per cycle as this adds complexity to the regulatory process as in practice cycle lengths may vary from the operational aims of an 18 month cycle and it is difficult to set limits to take into account any unexpected changes in cycle length.

39 For simplicity we use the term *Annual Limit* later in this report and in the Decision Document but it should be taken that this would be expressed in a permit as a *12 month rolling limit*. It should be noted that the values presented by EDF and AREVA are based on calendar year values and do not account for the impact of a 12 month rolling limit.

### 1.3.3 Limit setting

40 Our limit setting report recommends the use of a formula to determine the headroom which is appropriate to apply to average discharges to give operational flexibility and to take into account other conditions which might change during the period for which the limits would apply. The report recommends the use of a formula to calculate the “worst case annual plant discharge” (WCPD):

41  $WCPD = (1.5 \times D \times T \times A \times B) + C + L + N - I$  where:

- a) 1.5 is an Environment Agency-established factor which relates ‘worst case’ to average discharges and takes account of the requirement to minimise headroom.
- b) D is the representative average 12-month plant discharge. The average excludes discharges due to faulty operation of plant but includes discharges arising from minor unplanned events.
- c) T is a factor, which allows for any future increases in throughput, power output etc relative to the review period.
- d) A is a factor, which allows for plant ageing – that is, for increases in discharges which result from changes within the plant as it ages that cannot be remedied or controlled by the operator.
- e) B is a factor, which allows for other future changes that are beyond the control of the operator.
- f) C is an allowance for decommissioning work beyond that carried out in the review period (and included in D).
- g) L is an allowance for dealing with legacy wastes, beyond those dealt with in the review period (and included in D).
- h) N is an allowance for new plant.
- i) I is the reduction in discharges expected as a result of introducing improvement schemes before the new authorisation comes into force.

42 The discharge setting report recommends that WCPD for new plant should be a factor of 2 times the best estimate of discharges of radioactive waste.

43 Subsequent to the report Statutory Guidance (DECC, 2009) to us states that we should set limits:

- a) *based on the use of BAT; and*

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<sup>2</sup> Convention for the Protection of the Marine Environment of the North-East Atlantic, 1992 (“OSPAR Convention”)

- b) *at the minimum levels necessary to permit “normal” operation of a facility.*
- 44 Statutory Guidance also states that “*Where the prospective dose to the most exposed group of members of the public from discharges from a site at its current discharge limits is below 10  $\mu\text{Sv y}^{-1}$  the Environment Agency should not seek to reduce further the discharge limits that are in place, provided that the holder of the authorisation applies and continues to apply BAT*”. While this applies to existing sites we consider the 10  $\mu\text{Sv y}^{-1}$  is an appropriate guide to consider when deciding if BAT are used to minimise the impact of radioactive discharges for new sites.
- 45 We have assessed that the impact of radioactive discharges from the UK EPR to the most exposed person to be 31  $\mu\text{Sv y}^{-1}$  (our report EAGDAR UK EPR-11, see Environment Agency, 2011c). This indicates we need to actively challenge the EDF and AREVA BAT assertions. We indicate in our assessment below the impact attributable to each considered radionuclide or group of radionuclides and have targeted our assessment time at those with the highest contribution to the total. Where some radionuclides have only minimal contribution (much less than 10  $\mu\text{Sv y}^{-1}$ ) to the impact we have reduced our assessment time.
- 46 Our REPs reiterate the Statutory Guidance in relation to limits in the *Considerations* for principle RSMDP12:
- a) *limits should be based on the level of releases achievable by the use of BAT by operators;*
- b) *limits should be set such that there is a minimum headroom between actual levels of discharge expected during normal operation and the discharge limit.*
- 47 EDF and AREVA did not use the methodology of our limit setting guidance. They presented discharge data for radionuclides and groups of radionuclides in the PCER as:
- a) “*annual expected performance*” – the lowest annual discharge expected from a UK EPR with no contingency margin and no allowance for any operational failure;
- b) “*maximum annual discharge*” – combines the “*expected performance*” with contingencies derived from operation feedback data from predecessor reactors adapted to improvements expected from the UK EPR. The “*maximum*” may also include contingencies associated with management options. EDF and AREVA use a qualified descriptive justification to get from “*expected performance*” to “*maximum*”.
- 48 We have assessed the EDF and AREVA “*maximum*” proposals and where we believe justified have accepted them. Otherwise we have reviewed the information contained in the PCER and used it as far as possible within our own limit setting guidance to propose limits.

### 1.3.4 Notification level setting

49 Our REPs state, in the *Considerations* for principle RSMDP12, that advisory levels should be set that:

- a) *prompt review of whether the best available techniques are being used; and*
- b) *ensure early assessment of the potential impact of increased discharges.*

50 Advisory levels should also require early reporting of:

- a) *operational performance issues leading to increases in discharges; and*
- b) *events that have given rise to higher than normal short term discharges.*

51 We have in the past set quarterly, weekly or daily advisory levels. We consider that as the radioactivity discharges from the UK EPR are of a relatively low quantity and reasonably even over time that only quarterly notification levels (QNL) should be set.

52 The QNL is defined precisely by a condition in any permit we issue, a typical condition would be:

*If, in any quarter, the activity in waste discharged of any radionuclide or group of radionuclides specified in (the relevant Table) exceeds the relevant Quarterly Notification Level, the operator shall provide the Agency with a written submission which includes:*

- a) *Details of the occurrence;*
- b) *A description of the techniques used to minimise the activity of waste discharged;*
- c) *A review of those techniques having regard to the following:*
  - i) *The operator shall use the best available techniques to minimise the activity of radioactive waste produced on the premises that will require disposal to be disposed of on or from the premises;*
  - ii) *The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to:*
    - a) *minimise the activity of gaseous and aqueous radioactive waste disposed of by discharge to the environment;*
    - b) *minimise the volume of radioactive waste disposed of by transfer to other premises;*
    - c) *dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public.*

*Not later than 14 days from making the record which demonstrates such excess.*

53 The exceedence of a QNL set in a permit is not an offence. But it would be an offence for an operator to fail to notify us of the exceedence of a QNL in accordance with the relevant condition of the permit.

54 Normally we would use operational discharge data over at least 5 years to set QNLs. But as the UK EPR has not yet operated anywhere in the world we cannot do this at GDA. The simplest way to set a QNL would be to take a proportion of the annual limit, say 25%. However annual limits have contingency factors built in and we need to get early warning if discharges are above normal (without any contingency) so that we can ensure that BAT are still being used. We have therefore usually taken the “*expected performance*” figures quoted in the PCER as our start point to set QNLs. The detail of how we set each QNL is given below.

- 55 It is possible that with operational discharge data from EPRs currently under construction will become available during specific site permitting. We will review this and may need to revise the QNLs for any permit we issue.
- 56 Two respondents, both future operators (GDA106 and GDA127), were concerned that our rationale for setting QNLs as well as not being able to be based on operating data did not take account of operator or site-specific factors. We accept that different operators may have different waste management practices and there may be site-specific factors. Operators may propose their own basis for QNLs when applying for their permit. We have proposed an initial set of QNLs to show that we intend QNLs to reflect actual predicted discharges and provide notification to us for unusual discharges. The limits have contingencies built in and should not be considered as a starting point for QNLs.
- 57 An individual respondent (GDA123) considered some QNLs set at too high a level. When we have set a QNL at high level compared to a limit this is because we expect most of an annual discharge to be made in one quarter around a shutdown. We accept this may give us inadequate notification of high discharges in 'normal' operating times, we are considering using two levels of QNL, one for 'normal' operation and one for a shutdown period. This will need to be decided at site-specific permitting when we have the operators' proposed discharge management regime.
- 58 An individual respondent (GDA126) suggests QNLs should be based on limits but we use QNLs to help us ensure BAT is being used. QNLs should be based on expected normal discharges without any contingencies, a notification will warn us of unusual discharges and we can question if BAT was used. QNLs are therefore based directly on BAT, while limits take account of BAT but also include an allowance for reasonable contingencies.
- 59 An individual respondent (GDA38) asked that limits and QNLs be kept under review to ensure they are appropriate. We confirm that we review limits and QNLs whenever circumstances warrant this but also on a regular periodic basis.

## 2 Assessment

### 2.1 Assessment methodology

60 The basis of our assessment was to:

- a) read appropriate sections of the PCER and its supporting documents;
- b) hold technical meetings with EDF and AREVA to clarify our understanding of the information presented and explain any concerns we had with that information;
- c) raise Regulatory Observations and Technical Queries where we believed information provided by EDF and AREVA was insufficient;
- d) assess the techniques proposed by EDF and AREVA to minimise the discharge of gaseous radioactive waste using our internal guidance and regulatory experience and decide if they represent BAT;
- e) liaise with ONR on matters of joint interest;
- f) decide on any GDA Issues;
- g) identify assessment findings to carry forward from GDA.
- h) compare gaseous discharges from the UK EPR to ranges quoted in Annex 4 of the Decision Document (Environment Agency, 2011a);
- i) assess the EDF and AREVA proposals for limits, compare with our own methodology and then propose our own limits and levels.

### 2.2 Assessment objectives

61 We started our assessment with some key questions to answer:

- a) have all sources of gaseous radioactive waste been identified?
- b) have options for minimising the discharge of significant radionuclides that will be present in gaseous waste been presented?
- c) are the options chosen for the UK EPR BAT?
- d) are the discharges comparable to operating stations across the world?
- e) have annual gaseous disposal limits been proposed by EDF and AREVA?
  - i) is the derivation of the limits clear;
  - ii) are contingencies acceptable;
  - iii) have they taken account of our limit setting guidance (Environment Agency, 2005)?

## 2.3 EDF and AREVA documentation

62 The Pre-Construction Environmental Report is divided into chapters and sub-chapters (provided as separate documents) and has supporting documents. We referred to the following documents to produce this report:

Document reference	Title	Version number
UKEPR-0003-011	PCER-Sub-chapter 1.1 - Introduction	04
UKEPR-0003-030	PCER – Chapter 3 – Aspects having a bearing on the environment during operation phase	03
UKEPR-0003-061	PCER – Sub-chapter 6.1 – Sources of radioactive materials	04
UKEPR-0003-063	PCER – Sub-chapter 6.3 – Outputs for the Operating Installation	04
UKEPR-0003-064	PCER – Sub-chapter 6.4 - Effluent and waste treatment systems design architecture	04
UKEPR-0003-080	PCER – Chapter 8 – Best Available Techniques	02
UKEPR-0003-110	PCER – Chapter 11 – Radiological impact assessment	02
UKEPR-0011-001	GDA UK EPR-BAT Demonstration	04
UKEPR-0010-001	GDA UK EPR – Integrated Waste Strategy Document	02

63 We use short references in this report, for example:

- a) PCER sub-chapter 6.2 section 1.2.1 = PCERsc6.2s1.2.1;
- b) BAT Demonstration section 3.2 = EPRBs3.2.

## 2.4 Origins of gaseous radioactive waste

64 The PCERsc3.3s4.1.1.1 describes three origins of gaseous radioactive wastes:

- a) Degassing associated with the primary circuit. This waste will contain the radioactive gaseous products of fission and activation and will enter the Gaseous Waste Processing System (GWPS). The GWPS treats gaseous effluents from the systems serving the Reactor Coolant System:
  - i) The purge system (part of the GWPS) keeps a nitrogen flow through the free volumes of tanks and vessels. The nitrogen purge gas is mostly recovered by the GWPS and reused. During plant start-up or shut-down a portion of the purge gas is sent to a dryer and then three activated carbon delay beds in series, high efficiency particulate (HEPA) filters and iodine traps (if high iodine radioactivity is detected) before discharge.
  - ii) The degasification system is served by the purge system but is not normally used when the reactor is at power. It is usually used to treat coolant at shut-down and its waste gases sent through the purge system to the delay system (both purge and delay systems are part of the GWPS). The degasification system would only be used at power in the event of fuel failures leading to excessive levels of dissolved noble gases in the coolant.

(PCERsc6.2s1.2.3.1, diagram PCERsc6.4s3 Figure 1 (page 80), reproduced in the Annex to this report)

- b) The ventilation of buildings within the UK EPR that may be contaminated with radioactivity, in particular the Nuclear Auxiliary Building and the Fuel Building. Ventilation air that may contain radioactive particulates and gases, in particular iodine radionuclides (I-131 and I-133), is passed through filters and, if iodine detected, iodine traps before discharge. (PCERsc6.2s1.2.3.2 and Figure 10, reproduced in the Annex of this report)
  - c) Gaseous effluent from the secondary circuit. This would be mainly air collected in the condenser vacuum system that could be contaminated with radioactivity, particularly tritium, in the event of a tube leak in the steam generators. The collected gases are filtered before discharge, the pathway from the NAB (Nuclear Auxiliary Building) is shown in PCERsc6.2s1.2.3.2 Figure 10 (reproduced in the Annex of this report).
- 65 PCERsc8.2s3.4 provides EDF and AREVA's overall BAT assessment for minimising gaseous radioactive discharges. The box at the end of PCERsc8.2s3.4.6 gives a summary.
- 66 We have noted some techniques to reduce volumes of gaseous waste in our report EAGDAR UK EPR-03 (such as removal of air operated valves from the reactor building). We conclude that EDF and AREVA rely on the following abatement techniques to minimise the discharge of gaseous radioactivity:
- a) absorbent charcoal delay beds in the Gaseous Waste Processing System to reduce the activity of short lived radioactive gases such as xenon and krypton;
  - b) dry high efficiency particulate air (HEPA) filters (efficiency 99.97%) on all ventilation discharges;
  - c) "iodine traps" (activated carbon adsorption beds) available on all ventilation systems which could collect iodines to reduce discharges of iodine radionuclides. The ventilation air is routed to the traps by an automatic detection system or manually for prevention;
  - d) use of a semi-closed loop system for the treatment of aerated effluents, its advantages are listed in PCERsc6.3s7.4.1, reproduced in the Annex of this report.
- 67 EDF and AREVA claim that, depending on the level of primary coolant activity, gaseous radioactive discharges from the UK EPR can be reduced by 20% for noble gases and iodine radionuclides and by 15% for other fission and activation products as compared to the predecessor 1300 MWe design allowing for the increase in energy production. (PCERsc6.3s7.4.1).
- 68 PCERsc3.3s4.1.2 Table 4 states that the UK EPR will make radioactive discharges to air through the main stack as given in the Table below. We have added to that Table our proposed disposal limits and levels, which are explained further later in our document.



69

Note that the base case discharges for the UK EPR do not include any associated waste and spent fuel storage facilities, our limits do not include any allowance for possible gaseous disposals from these facilities.

Category	Annual expected performance excluding contingency (GBq)	Maximum annual gaseous radioactive discharge (GBq)	Proposed Environment Agency Annual Limits (GBq)	Proposed Environment Agency QNL (GBq)
Tritium	500	3000	3000	200
Carbon-14	350	700	700	100
Iodine-131	0.0228	0.18	0.4	0.04
Total iodine radionuclides	0.05	0.4	None	
Noble gases	800	22500	22500	2250
All other radionuclides (excepting tritium, carbon-14, iodine radionuclides and noble gases)	0.004	0.12	0.05	0.027

70

Some respondents sought clarification of the terms used above.

- a) The 'annual expected performance' is the estimate of discharges from the UK EPR provided by EDF and AREVA based on 'best quartile' of predecessor plants allowing for design improvements. It is a 'best' estimate of the annual average discharge containing no contingencies.
- b) The 'maximum' is the limit proposed by EDF and AREVA for a UK EPR including contingencies to cover all foreseeable events likely to occur in normal operation. We do not always accept the level of contingency requested.

- 71 The above estimates are expanded into individual radionuclides in the PCERsc3.3s4.1.2 Table 5. We are content these represent the significant radionuclides potentially discharged to the air.

Category of radionuclide	Expected performance	Maximum annual activity
I 131	0.0228 GBq	182.4 MBq
I 133	0.0272 GBq	217.6 MBq
<i>Total iodine isotopes</i>	0.05 GBq	400 MBq
Kr 85	111.2 GBq	3.1275 TBq
Xe 133	504.8 GBq	14.1975 TBq
Xe 135	158.4 GBq	4.455 TBq
Ar 41	23.2 GBq	0.6525 TBq
Xe 131m	2.4 GBq	0.0675 TBq
<i>Total noble gases</i>	800 GBq	22.5 TBq
Co 58	0.00102 GBq	30.6 MBq
Co 60	0.001204 GBq	36.1 MBq
Cs 134	0.000936 GBq	28.1 MBq
Cs 137	0.00084 GBq	25.2 MBq
<i>Total FP / AP</i>	0.004 GBq	120 MBq (**)

Sub-chapter 3.3 – Table 5: Split of activity between iodine isotopes, noble gases and fission and activation products (expected performance and estimated maximum values)

- 72 We will set limits and levels on the quantities of radioactivity that can be discharged into the environment where these are necessary to secure proper protection of human health and the environment. We have assessed the information within the PCER against our criteria described above as follows:

- a) critical group dose greater than  $1 \mu\text{Sv y}^{-1}$ : carbon-14 at  $5.6 \mu\text{Sv y}^{-1}$ ;
- b) discharge exceeds  $1 \text{TBq y}^{-1}$ : tritium and noble gases;
- c) indicator of plant performance:
  - i) iodine radionuclides for fuel pin failures, we will use iodine-131 as an indicator;
  - ii) “all other radionuclides” to be monitored as particulates will confirm performance of filters in the ventilation systems.

- 73 We have set out our proposed disposal limits for tritium, carbon-14, noble gases, iodine-131 and other radionuclides in the Table above. The definition of “all other radionuclides” will be specified more completely in our permit with reference to the monitoring technique to be employed.

- 74 PCERsc6.3s7.2 to s7.5 quantifies disposals, these are given as “expected performance” that has no allowance for any contingencies and “maximum” (we have taken as the proposed disposal limit) that allows for contingencies to cover situations foreseeable in normal operations but not any incidents.

- 75 Our assessment concluded that:

- a) all sources of gaseous radioactive waste have been identified;
- b) the nature and form of gaseous radioactive waste has been identified in enough detail to demonstrate that treatment processes and disposal routes can be envisaged for all gaseous radioactive waste;
- c) the data provided by EDF and AREVA relating to the sources of gaseous radioactive waste is comprehensive, justified and reasonable at the GDA stage.

## 2.5 BAT, limits and QNLs

76 The PCERsc6.2s1.2.2 covers the nature and treatment of the gaseous disposals. We summarise the PCER and the UK EPR BAT demonstration (EPRB) information below for individual radionuclides and groups, give our BAT conclusions and detail our limit and QNL proposals.

### 2.5.1 Tritium

77 The main sources of tritium for gaseous disposal are tritiated water evaporating from the surface of the in-containment refuelling storage water tank (IRWST) and the spent fuel pool and collected by the ventilation systems. EDF and AREVA claim maximum losses by evaporation are 350 GBq y<sup>-1</sup> from the pool and 500 GBq y<sup>-1</sup> from the IRWST, with realistic values below these figures. Disposal is to the main stack.

78 EDF and AREVA claim that ventilation system design reduces evaporation of tritium but do not provide evidence or quantification of this.

79 EDF and AREVA say that evaporation of tritium from the pool and the IRWST depends on the [pool's temperature](#), ambient temperature and hygrometry. Operating conditions need to be optimised by the operator at the site-specific stage between the health and safety of workers in the building, the operating conditions of equipment and reduction of evaporation of tritium.

80 We will require a BAT case for control of tritium resulting from evaporation in the UK EPR in applications for site-specific permitting.

81 Tritium will also be present in the gaseous effluent from the primary coolant treatment systems. This effluent is processed in the Gaseous Waste Processing System. We noted in our assessment report EAGDAR UK EPR-03 (Environment Agency, 2011b) that the GWPS minimises discharge of tritium to air.

82 [Another possible pathway for tritium discharge is in the event of leaks in or diffusion through the tubes between the primary and secondary circuits in the steam generators. The steam in the secondary circuit may then contain some tritium, the steam is condensed after passing through the turbines and the condenser off-gas is collected and feeds into the ventilation systems where it is filtered through HEPA filters and iodine traps \(if iodine detected\) before discharge.](#)

83 EDF and AREVA review gaseous abatement techniques (EPRBs3.3) but do not consider any represent BAT:

- a) decay by delay is not an option as the half-life of tritium is 12 years;
- b) filtration does not affect tritium in gaseous effluent;
- c) oxidising the gaseous effluent and then adsorption of the tritiated water produced on molecular sieve is possible. The sieve could be disposed of as solid waste or the tritiated water desorbed by heat and discharged as liquid effluent.
- d) scrubbing with chilled water will move tritium to liquid effluent. The low level of tritium in the gaseous route (2-3% of UK EPR total) and inefficiency of the scrubbing process mean any cost would be disproportionate to the benefit in reducing the gaseous impact.

84 Tritium discharges have a relatively low impact on the environment (see below - 0.26 µSv y<sup>-1</sup> to an infant). We therefore agree that the use of any of the gaseous abatement techniques considered is disproportionate for the UK EPR.

85 [Our assessment concluded that the UK EPR uses BAT to minimise discharges of gaseous tritium, although we expect the operator to demonstrate that controls on](#)

- the fuel pool are BAT to minimise the discharge of tritium to air at the site-specific stage (assessment finding UK EPR-AF07).
- 86 EDF and AREVA estimated the expected performance value of 500 GBq y<sup>-1</sup> using operational feedback from currently operating similar reactors, allowing for differences in pool surface area.
- 87 EDF and AREVA cited current limits for similar but smaller plants and operational experience of an annual maximum reaching 1000 GBq to propose a maximum annual disposal for the UK EPR of 3000 GBq. (PCERsc6.3s7.2.2.1)
- 88 We examined historic discharges from European and US PWRs operating over the last 10 to 15 years and consider that the range of discharges to atmosphere of tritium is 100 to 3600 GBq per year for a 1000 MWe power station. We conclude that the gaseous discharge of tritium from UK EPR at the “expected performance” of 500 GBq (290 GBq normalised to 1000 MWe) is comparable to other power stations across the world.
- 89 EDF and AREVA state that the monthly disposal profile is unlikely to present major fluctuations. Values at 10% of the annual are quoted: 50 GBq/month “expected performance” and 300 GBq/month “maximum”. (PCERsc6.3s7.2.2.2)
- 90 The radiological impact from the “maximum” disposal of tritium to air is stated as a dose to adults and children of 0.14 µSv y<sup>-1</sup> and infants of 0.26 µSv y<sup>-1</sup> – from PCERsc11.1 Annex 3 Tables B, C and D. We do not consider the impact as particularly significant.
- 91 EDF and AREVA propose a gaseous disposal limit for tritium of 3000 GBq y<sup>-1</sup>. They state that as a new design there are some uncertainties as to the actual evaporation rates leading to tritium disposals and that an improved monitoring method for tritium may report higher values than historic data from existing reactors. Hence the headroom of 2500 GBq above the 500 GBq “expected performance” is proposed until operational experience of an EPR is available.
- 92 We concluded above that the UK EPR uses BAT to minimise the gaseous discharge of tritium with an “expected performance” value of 500 GBq y<sup>-1</sup>. The limit set should allow some headroom above this value to allow for foreseeable contingencies. We have considered the operational data presented in PCERsc6.3 Appendix A-24 and A-25 for previous similar plant and have taken 1000 GBq y<sup>-1</sup> as a worst case operational estimate. Allowing for the larger size of the UK EPR could give up to (1735/900 x 1000 = 1928) and a contingency factor up to x2, the EDF and AREVA proposal to set the annual disposal limit at 3000 GBq is acceptable.
- 93 We consider that a quarterly notification level based on the 'expected performance' (500 GBq y<sup>-1</sup>) and the stated monthly estimate of 10 per cent of annual should be set plus an allowance for operational fluctuations. That is 3 x 50 = 150 GBq/quarter, we will add 50 GBq as an allowance giving a QNL of 200 GBq. This should highlight adverse trends in disposals and require an operator to demonstrate that BAT is still being applied if a QNL is exceeded.

## 2.5.2 Carbon-14

- 94 As described in our report EAGDAR UK EPR-03 (Environment Agency, 2011b) the main source of carbon-14 is the activation of oxygen and nitrogen in the reactor coolant. The carbon-14 is mainly present as the dissolved gases methane (CH<sub>4</sub> – about 80%) and carbon dioxide (CO<sub>2</sub> - 20%). A portion of the coolant continually passes through the Chemical and Volume Control System where dissolved gases are sent to the Gaseous Waste Processing System (GWPS). The GWPS does not remove any carbon-14. EDF and AREVA state that 80 – 95% of the carbon-14 in the coolant will discharge as a gas with 5-20% remaining in liquid or solid wastes. (PCERsc6.3s7.3.1.3)
- 95 EDF and AREVA have considered techniques to minimise the gaseous discharge of carbon-14 (EPRBs3.2) in particular:
- a) Decay by delay is not an option as the half-life of carbon-14 is 5710 years.
  - b) Thermal oxidation to ensure all carbon-14 is converted to carbon dioxide (CO<sub>2</sub>) followed by scrubbing, e.g. with sodium hydroxide solution, to remove the CO<sub>2</sub> as a carbonate. The carbonate would be as a suspended solid and can be removed from the scrubber solution (e.g. by filtration) and converted to a solid waste for disposal.
  - c) Thermal oxidation, as above, followed by CO<sub>2</sub> absorption in a cooled fluorocarbon or ethanolamine solvent. The matter of dealing with the absorbed CO<sub>2</sub> is not resolved.
  - d) Thermal oxidation, as above, followed by CO<sub>2</sub> adsorption on molecular sieve. The matter of dealing with the molecular sieve after saturation is not resolved.
  - e) Thermal oxidation, as above, followed by freezing out the CO<sub>2</sub>. The matter of dealing with the removed CO<sub>2</sub> is not resolved.
- 96 EDF and AREVA state that while there are potential techniques for the reduction of carbon-14 in gaseous effluents, none are currently used on operational power reactors and they do not therefore represent world best practice. Also some are not sufficiently technically developed for use in a PWR. They cite the IAEA Technical report 421 that concludes that carbon-14 removal methods are costly and require high energy consumption but do not provide any cost or energy estimates for applying any techniques to the UK EPR. EDF and AREVA consider that the impact from the gaseous disposal of carbon-14 is low (a maximum of 5.6 μSv y<sup>-1</sup> for an infant) and conclude that no technique is BAT for use in the UK EPR.
- 97 Our assessment confirmed that no techniques appear to be BAT at this time for reducing carbon-14 in gaseous discharges from a PWR. We concluded that the UK EPR uses BAT to minimise the discharge of carbon-14 to air.
- 98 EDF and AREVA predict an “expected performance” value of 350 GBq y<sup>-1</sup> based on the 444 GBq y<sup>-1</sup> source term assuming some 80% of carbon-14 produced goes to air. They state that the split of carbon-14 to solid / liquid and to gas is uncertain. Also the level of dissolved nitrogen in the coolant may increase from 10 ppm (value used for source term). Therefore they propose a maximum annual disposal for the UK EPR of 700 GBq. This value is supported by operational data from predecessor KONVOI reactors.
- 99 We examined historic discharges from European and US PWRs operating over the last 10 to 15 years and consider that the range of discharges to atmosphere of carbon-14 is 40 to 350 GBq per annum for a 1000 MWe power station. The “expected performance” gaseous discharge of carbon-14 from UK EPR is 350 GBq that normalises to 203 GBq at 1000 MWe. We conclude that gaseous discharge of carbon-14 is comparable to other power stations across the world.
- 100 EDF and AREVA were unable to provide a monthly discharge profile but did provide quarterly data based on operational feedback (PCERsc6.3s7.3.3). Discharges are

- affected by power output and factors such as shut-downs. They are variable and a significant portion of annual discharge can occur in one quarter. Values of 100 GBq/quarter “expected performance” and 300 GBq/quarter “maximum” are quoted.
- 101 The radiological impact from the “maximum” disposal of carbon-14 to air is stated as a dose to adults of  $2.9 \mu\text{Sv y}^{-1}$ , to children of  $3.2 \mu\text{Sv y}^{-1}$  and infants of  $5.6 \mu\text{Sv y}^{-1}$  – from PCERsc11.1 Annex 3 Tables B, C and D, corrected from 900 to 700 GBq  $\text{y}^{-1}$ . This is the most significant impact from gaseous discharges but is tolerable. As the source of carbon-14 cannot be minimised then abatement of carbon-14 will be an important matter for future BAT reviews.
- 102 We accepted above that the UK EPR uses BAT to minimise the gaseous discharge of carbon-14 with an “expected performance” value of  $350 \text{ GBq y}^{-1}$ . We accept the headroom proposed of  $350 \text{ GBq y}^{-1}$  to allow for the uncertainty of split between gas and liquid and level of nitrogen in the coolant. This is also equivalent to a x2 factor using our methodology, we will set the annual disposal limit at 700 GBq.
- 103 We consider that a quarterly notification level based on the “expected quarterly performance” of 100 GBq should be set.

### 2.5.3 Noble gases

- 104 Significant quantities of xenon and krypton isotopes (in particular, xenon-133, xenon-135 and krypton-85) should only reach the Gaseous Waste Processing System (GWPS) in the event of defects in fuel cladding. The integrity of fuel is discussed under the noble gases section of our report EAGDAR UK EPR-03.
- 105 *COMARE (GDA129) made some important points on fuel integrity: ‘Both designs depend to a great extent on the manufacturing quality control and reliability of fuel elements in order to control waste arisings. It will be important to ensure that operators adhere to the intended operating standards over the lifetime of the plant and that it is made mandatory to implement any improvements made by the manufacturers. What arrangements would be available if current manufacturers went out of business? We support the EA approach of using QNLs in order to give early warning of problems arising from fuel assemblies.’*
- 106 *Our permit conditions require operators to use and review BAT, the scope of which includes fuel integrity matters. There are a number of suppliers of nuclear fuel worldwide and operators are free to select an appropriate manufacturer based on relevant criteria, for example on technical and commercial specifications. Irrespective of who manufactures the nuclear fuel, operators will need to ensure that any fuel used in their reactors meets quality expectations and that its design represents BAT. The QNL we set below is intended to alert our Inspectors to any fuel issues to enable early investigation and possible intervention.*
- 107 The GWPS is designed to minimise the impact of noble gas by delaying their discharge using activated charcoal beds. The noble gases are initially adsorbed but are gradually moved forward by fresh purge gas passing through the beds. The delay allows the radioactivity to decay (PCERsc6.3s7.4.2.1). Xenon is delayed by 40 days – for xenon-131 with a half-life of 5.25 days this will reduce radioactivity to less than 0.5% of the value entering the GWPS (reduction factor of 200). Krypton is delayed by at least 40 hours giving effective decay of the short lived radionuclides krypton-85m (reduction factor of 500 claimed), krypton-87 and krypton-88 but not krypton-85 with a half life of 10.72 years. There is a gas drier before the delay beds to optimise their performance and a filter after to prevent any dust from the beds escaping to the air. The gaseous effluent from the GWPS is discharged to the main stack through HEPA filters located in the Nuclear Auxiliary Building. (PCERsc6.2s1.2.3.1)

- 108 EDF and AREVA provided us with their design calculations confirming that the activated charcoal in the 3 beds would achieve the delays promised above but did not provide a full BAT options appraisal of alternative techniques or bed sizing.
- 109 Our assessment confirmed the delay calculations and that delay beds are current good practice. Further, that the impact from noble gases is low ( $0.047 \mu\text{Sv y}^{-1}$ ) so that a full BAT assessment would be disproportionate. We conclude that the UK EPR uses BAT to minimise the discharge of noble gases.
- 110 PCERsc6.3s7.4.2.1 Table 16 gives the expected distribution of noble gas radionuclides based on data from similar predecessor reactors:

Radionuclide	Percentage of total noble gas activity discharged
Krypton-85	13.9
Xenon-133	63.1
Xenon-135	19.8
Argon-41	2.9
Xenon-131m	0.3

- 111 Argon-41 is discussed in our report EAGDAR UK EPR-03 (Environment Agency, 2011b), its source is activation of naturally occurring argon-40 in the air around the reactor and it is sent to the main stack by the ventilation systems. It does not pass through the GWPS but is monitored in the stack before discharge. We decided that argon-41 is not a significant contributor to the dose impact and does not require a BAT assessment.
- 112 EDF and AREVA estimated their “expected performance” value of  $800 \text{ GBq y}^{-1}$  using operational feedback data from predecessor reactors. This value can only be achieved if there are no fuel cladding failures and a subsequent need to degas the reactor coolant during a reporting year. The operational data is highly variable showing dependency on fuel reliability. EDF and AREVA say that a sizable contingency is needed to allow for continued operation with even a very low level of fuel failure. They propose a “maximum” of  $22,500 \text{ GBq y}^{-1}$  – the same as the current limit in France for the 1300 MWe reactor. As the UK EPR will generate 25% more energy they say this is effectively a 25% lower limit and reflects the better performance expected of fuel today. (PCERsc6.3s7.4.2.1, s7.4.2.2.1)
- 113 We examined historic discharges from European and US PWRs operating over the last 10 to 15 years and consider that the range of discharges to atmosphere of noble gases is 100 to 10,000 GBq per year for a 1000 MWe power station. The “expected performance” gaseous discharge of noble gases from UK EPR at  $800 \text{ GBq}$  ( $460 \text{ GBq}$  normalised to 1000 MWe) is well within this range. We conclude that gaseous discharge of noble gases is comparable to other power stations across the world.
- 114 EDF and AREVA say that in normal operation (without fuel leaks or degassing before shutdown) monthly discharges could be below detectable quantities. Monitoring systems would report at detection thresholds and this could be  $400 \text{ GBq/month}$ . However with fuel leaks and if the reactor coolant is degassed the monthly discharge could reach  $5000 \text{ GBq}$ . (PCERsc6.3s7.4.2.2)
- 115 The radiological impact from the “maximum” disposal of noble gases to air is stated as a dose to adults of  $0.047 \mu\text{Sv y}^{-1}$ , to children of  $0.029 \mu\text{Sv y}^{-1}$  and infants of  $0.023 \mu\text{Sv y}^{-1}$  – from PCERsc11.1 Annex 3 Tables B, C and D. We do not consider this level of impact particularly significant.

- 116 We have accepted above that the UK EPR uses BAT to minimise the gaseous discharge of noble gases with an “expected performance” value of  $800 \text{ GBq y}^{-1}$ . EDF and AREVA propose a headroom of 21,700 GBq to allow for some level of fuel cladding failure. In our limit considerations we accept that predicting an allowance for fuel leaks is difficult. Reactors are designed to run until their next refuelling shutdown with a small number of fuel leaks and we do not wish to constrain operations when noble gas discharges have so little impact. We stated our range above as up to  $10,000 \text{ GBq y}^{-1}$  and, using this as a base value of discharge with a level of fuel failures, we need to allow for the increased size of the UK EPR, say  $(10000 \times 1735/1000 = 17350)$  and to add some contingency, say up to x2, to set a limit. On that basis we consider the EDF and AREVA proposal reasonable and we will set the annual disposal limit at 22,500 GBq.
- 117 We consider that a quarterly notification level should be set to give us early indications of fuel cladding failures. Based on our Regulatory experience setting the QNL at 10% of the disposal limit - 2250 GBq – gives a level that should be above levels of detection but should be reached with a low level of failure.

#### 2.5.4 Iodine radionuclides

- 118 As described in our report EAGDAR UK EPR-03 (Environment Agency, 2011b) iodine radionuclides are formed by fission in the fuel and are normally contained within the fuel cladding. The integrity of fuel is discussed under the noble gases section 2.7.5 of our report EAGDAR UK EPR-03 (Environment Agency, 2011b), use of AREVA AFA 3GLE fuel assemblies is considered BAT. Section 2.7.6 concludes that the UK EPR uses BAT to minimise creation of iodine radionuclides needing disposal.
- For the iodine radionuclides that are not contained by the cladding and enter the reactor coolant most are retained within the liquids going to the Liquid Waste Processing System (PCERsc6.3s7.4.3.1). Gaseous iodines will enter the Gaseous Waste Processing System (GWPS) with the noble gases as described above. The recirculation of purge gas in the GWPS will allow decay of shorter-lived iodine radionuclides such as iodine-132 and iodine-134. When purge gas is bled off, it passes through delay beds before discharge. While these beds are not targeted at iodines, EDF and AREVA claim a delay of 40 days in the delay beds for iodine radionuclides. Iodine-131 has a half-life of 8 days so a reduction to around 3% of the input value should take place. Other shorter lived iodine radionuclides will undergo even greater decay. (EPRBs3.6)
- 119 The effluent gas from the GWPS is passed to HEPA filters before discharge from the main stack. There is a detection system to pass the gas through activated charcoal iodine traps before discharge if high iodine radioactivity is detected. EDF and AREVA claim a decontamination factor of 100 for the iodine traps in systems that operate during fault conditions and 10 for others. (PCERsc6.2s1.2.3.2.1)
- 120 Any iodine radionuclides coming from leaks in the primary coolant circuit will enter the ventilation systems. These systems will send ventilation air to activated charcoal iodine traps if high iodine radioactivity is detected or as a precaution during certain operations or in case of accidents. (PCERsc6.3s7.4.3.1 Figure 16, reproduced in the Annex of this report).
- 121 EDF and AREVA have not presented evidence that the techniques described above for the abatement of iodine radionuclides are BAT. We do accept the use of activated charcoal as current good practice for minimising the discharge of iodine radionuclides and as the level of discharge ( $50 \text{ MBq}$ ) and subsequent impact (maximum  $0.32 \mu\text{Sv y}^{-1}$ ) are low we accept that a detailed BAT assessment would be disproportionate. We conclude that the UK EPR uses BAT to minimise the discharge of iodine radionuclides to air.



- 122 EDF and AREVA calculated an “expected performance” value of  $50 \text{ MBq y}^{-1}$  using operational feedback data from predecessor reactors. This may be high as much data showed “below detection limit”. This value can only be achieved if there are no fuel cladding failures and subsequent release of iodine radionuclides. The operational data for “maximums” is highly variable showing dependency on fuel reliability. EDF and AREVA say that a sizable contingency is needed to allow for continued operation with even a very low level of fuel failure. They propose  $400 \text{ MBq y}^{-1}$  – the same as the current limit in France for the 1300 MWe reactor. As the UK EPR will deliver 25% more energy this is effectively a 25% lower limit and reflects the better performance expected of fuel today and the improvements made to the GWPS.
- 123 We examined historic discharges from European and US PWRs operating over the last 10 to 15 years and consider that the range of discharges to atmosphere of iodine radionuclides is 1 to 2000 MBq per year for a 1000 MWe power station. The “expected performance” gaseous discharge of iodine radionuclides from UK EPR at  $50 \text{ MBq}$  ( $29 \text{ MBq}$  normalised to 1000 MWe) is well within this range. We conclude that gaseous discharge of iodine radionuclides is comparable to other power stations across the world.
- 124 EDF and AREVA claim that in normal operation (without fuel leaks) and without shut-downs or maintenance activities monthly discharges are very low and could be below detectable quantities, a value of  $20 \text{ MBq}$  is proposed. However most iodine radionuclides discharges are expected during shut-downs or maintenance activities when large volumes can be processed through the GWPS, if this also happens when there are fuel leaks the discharge could reach 75% of the maximum annual discharge so the proposed maximum monthly discharge is  $300 \text{ MBq}$ .
- 125 The radiological impact from the “maximum” disposal of iodine radionuclides to air is stated as a dose to adults of  $0.039 \mu\text{Sv y}^{-1}$ , to children of  $0.078 \mu\text{Sv y}^{-1}$  and infants of  $0.32 \mu\text{Sv y}^{-1}$  – from PCERsc11.1 Annex 3 Tables B, C and D.
- 126 We conclude above that the UK EPR uses BAT to minimise the gaseous discharge of iodine radionuclides with an “expected performance” value of  $50 \text{ MBq y}^{-1}$ . The headroom proposed allows for some level of fuel cladding failure – the PCER says past operational experience has seen discharge levels increase by a factor of up to 10 following fuel leaks. We noted above that we would only set a limit against iodine-131 as it has the greatest individual impact of the iodine radionuclides. Also the impact of iodine radionuclides is low and we wish to provide adequate headroom to avoid constraining operations. On that basis we will set the annual disposal limit for iodine-131 at  $400 \text{ MBq}$ .
- 127 We consider that a quarterly notification level should be set to give us early indications of fuel cladding failures. We will set the QNL at 10% of the disposal limit (as noble gases above) -  $40 \text{ MBq}$ .

## 2.5.5 Other radionuclides

128 EDF and AREVA say in PCER sc6.3s7.4.4.1 that other fission and activation products (FAPs) are present in the reactor coolant and can be in aerosols (a dispersion of solid or liquid particles in a gas) produced from equipment leaks or as the coolant is treated in the Chemical and Volume Control System (CVCS). Most FAPs remain in the liquid phase. Aerosols from equipment leaks are picked up by the ventilation systems, these systems have HEPA filters that should effectively remove the aerosols before discharge to the main stack. FAPs can be in the gaseous effluent from the CVCS to the Gaseous Waste Processing System (GWPS). The gaseous effluent from the GWPS passes through HEPA filters before discharge to the main stack. We conclude that the use of HEPA filters in the UK EPR on all gaseous discharges that may contain FAPs is BAT.

129 PCERsc6.3s7.4.4.1 Table 17 gives the distribution of the main fission and activation product radionuclides expected to be found as particulates in the gaseous discharge:

Radionuclide	Percentage of activity in discharged Fission and Activation Products (FAPs)
Cobalt-58	25.5
Cobalt-60	30.1
Caesium-134	23.4
Caesium-137	21.0

130 Caesium is a fission product and should only be detected on fuel cladding failures, cobalt is an activated corrosion product and can be present in trace quantities. Discharges are often below the threshold of detection of monitoring equipment.

131 EDF and AREVA calculated an “expected performance” value of 4 MBq y<sup>-1</sup> using operational feedback from predecessor reactors. Values of FAPs were below the detection limits of monitoring equipment and the 4 MBq is in essence a threshold of detection value. Peaks of discharge can be seen however during shut-downs and maintenance activity and significant contingency should be allowed to cover these operations. EDF and AREVA used the current limit value for their predecessor 1300 MWe reactors of 400 MBq y<sup>-1</sup> as a start point for proposing the “maximum” discharge. They claim that the UK EPR has improvements over the 1300 MWe reactor with improved HEPA filtration and the source of cobalt has been minimised by use of low cobalt content material. The “maximum” proposed is 120 MBq y<sup>-1</sup> – less than 25% of the 1300 MWe reactors if the increased power of the UK EPR is taken into account.

132 We examined historic discharges from European and US PWRs operating over the last 10 to 15 years and consider that the range of discharges to atmosphere of fission and activation products is 1 to 1000 MBq per year for a 1000 MWe power station. The “expected performance” gaseous discharge of FAPs from UK EPR at 4 MBq (2.3 MBq normalised to 1000 MWe) is well within this range. We conclude that gaseous discharge of FAPs is comparable to other power stations across the world.

133 EDF and AREVA claim that in normal operation (without fuel leaks to contribute caesium) and without shut-downs or maintenance activities monthly discharges are very low and could be below detectable quantities, the “predicted performance” value of 0.8 MBq is proposed. However in a month before shut-down or when maintenance is undertaken and allowing for some fuel leaks combined with any

- treatment failures a much higher value is required for the monthly “maximum”. Up to 50% of the annual discharge could occur in a month – 60 MBq is proposed.
- 134 The radiological impact from the “maximum” disposal of other FAPs to air is stated as a dose to adults of  $0.018 \mu\text{Sv y}^{-1}$ , to children of  $0.01 \mu\text{Sv y}^{-1}$  and infants of  $0.009 \mu\text{Sv y}^{-1}$  – from PCERsc11.1 Annex 3 Tables B, C and D, corrected from previous maximum of 340 to 120 MBq  $\text{y}^{-1}$ . We consider these values as not particularly significant.
- 135 We have accepted above that the UK EPR uses BAT to minimise the gaseous discharge of other FAPs with an “expected performance” value of  $4 \text{ MBq y}^{-1}$ . As well as comparing their “maximum” with current limits, EDF and AREVA say that ‘*in the event of fuel leaks combined with failure of the treatment systems, the monthly discharges would drastically increase and it can be expected that values as high as 60 MBq/month could be reached*’. Hence the requirement for the large headroom,  $116 \text{ MBq y}^{-1}$ , between the annual expected performance and the maximum discharge value. (PCERsc6.3s7.4.4.3)
- 136 We do not consider this approach justified, in particular when operational data provided in the PCERsc6.3 Appendices A-55 and A-56 is taken into account. The highest discharge reported in the 6 years from 2002 to 2007 was less than  $6 \text{ MBq y}^{-1}$ . The values reported are often less than 1% of limits. We note that some higher levels, up to  $50 \text{ MBq y}^{-1}$ , are reported in the PCER but without the context to these numbers we cannot assess whether they represent normal operational variance or events. We set limits to ensure BAT is used. While we allow for contingencies we believe that, using BAT, a failure of HEPA filtration should be rapidly detected and any ventilation involved should be diverted to functioning equipment quickly. Further, operations that may cause high discharges should not be undertaken when key equipment such as HEPA filters are unavailable. Our normal methodology is to take the worst case discharge from operational experience and then add an appropriate contingency. We have considered the data provided and taken  $25 \text{ MBq y}^{-1}$  as a worse case normal operational discharge. We have applied a x2 factor (Environment Agency, 2005) and propose to set  $50 \text{ MBq y}^{-1}$  as the annual disposal limit.
- 137 NNB GenCo (GDA106) submitted the following response:
- a) *“...the proposals in the consultation document for limits on ‘other radionuclides’, which include the fission products released following fuel cladding failure, appear unduly restrictive. Minor fuel cladding failures are foreseeable. Since gaseous discharges are continuous, a short-term defect in abatement plant (such as HEPA filters) – even if quickly resolved by diversion to alternative plant – will result in increased discharges if it coincides with a cladding failure event. However, such events should not require disproportionate action such as immediate shut-down, as long as their impact is demonstrated to be below the threshold where, under Environment Agency guidance, further action to reduce dose is required. In accord with this, the consultation document recognises that cladding failure can have small impact, but requires significant headroom within the discharge limits to accommodate this without constraining operation. To account for this contingency, there should be a difference between the discharge limits and the expected best performance. This difference was recognised in the Requesting Party’s evidence, but it has not been reflected in the proposals for lower limits in the consultation document. We therefore believe that these proposals would represent an artificial and disproportionate constraint, not informed by the specific risks and impacts for any individual site. Instead, we believe that the system of Quarterly Notification Levels (QNLs) is the appropriate tool to ensure that such events are visible to the Environment Agency and to monitor the operator’s effectiveness in applying BAT to minimise deviation from expected best performance.”*

- 138 We acknowledge this comment but, as noted above, we do not consider that EDF and AREVA have provided adequate evidence to justify an increased limit.
- 139 We consider that a quarterly notification level should be set to give us early indications of any issues. We will allow one month at 50 % of the disposal limit and two months at the “expected performance” of 0.8 MBq per month and round up to give a QNL of 27 MBq.
- 140 An individual respondent (GDA119) was concerned that we were not putting a zero limit on alpha-emitting radionuclides and about the sensitivity of detection methods. We discuss the source and type of potential alpha-emitters in section 8.3.6 of this document. There is no expected discharge of alpha-emitters but we will require monitoring as a precaution. The monitoring method will be specified by future operators, we will require the best available techniques at time of installation<sup>3</sup>. The use of ‘zero’ limits is difficult as measurements can usually only be stated as ‘below limit of detection’ and at very low levels measurements can be affected by trace background interference, a true zero measurement is almost impossible to achieve. We prefer to rely on the standard BAT conditions in our permits that, in this case, would require operators to demonstrate effectively zero discharge of alpha-emitting radionuclides.

## 2.6 Gaseous radioactive waste disposal to the environment

- 141 We are satisfied that all significant gaseous radioactive wastes from the UK EPR are collected into the main stack for discharge. The stack will be fitted with continuous monitoring equipment to measure radioactive materials entering the air.
- 142 The PCER has assumed an “effective” stack height of 20 m for GDA. The effective stack height allows for factors such as effect of nearby large buildings causing downwash, which results in discharges reaching the ground closer to the point of discharge than in an open area. The effective height is much less than the actual height, the initial estimate for the UK EPR stack is 60 metres. Dispersion modelling for the generic site gives an annual dose from the “maximum” gaseous discharge of 4 µSv for an adult or child and 7.8 µSv for an infant (PCERsc11.1s1.3.2.2). The doses are sufficiently low that we accept that the (GDA) stack is BAT to reduce impact to a minimum. The operator for each specific site will need to demonstrate by modelling that the stack height proposed will be BAT for adequate dispersion allowing for topography (the surface features of the local land area surrounding the site).

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<sup>3</sup> We are revising our monitoring guidance M11 but this will be available for future operators to apply. We also require monitoring to conform to the European Commission’s (EC) recommendation 2004/2/Euratom) on standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation. See our joint guidance with SEPA: [http://www.sepa.org.uk/radioactive\\_substances/publications/doc.ashx?docid=cefd6d99-5000-4fd5-b028-5f8a39efc7a0&version=-1](http://www.sepa.org.uk/radioactive_substances/publications/doc.ashx?docid=cefd6d99-5000-4fd5-b028-5f8a39efc7a0&version=-1).

### 3 Public comments

- 143 The public involvement process remained open during our assessment see <http://www.hse.gov.uk/newreactors/publicinvolvement.htm>
- 144 We did not receive any public comments by this route during this assessment relating to gaseous radioactive waste disposal and limits.
- 145 The conclusions in this report have been made after consideration of all relevant responses to our consultation.

### 4 Conclusion

- 146 We conclude that the UK EPR utilises the best available techniques (BAT) to minimise discharges of gaseous radioactive waste:
- a) during routine operations (subject to assessment finding UK EPR-AF07) and maintenance;
  - b) from anticipated operational events.
- 147 We conclude that the gaseous discharges from the UK EPR should not exceed those of comparable power stations across the world.
- 148 We conclude that any operational, single UK EPR unit should comply with the limits and levels set out below for the disposal of gaseous radioactive waste to air. The limits and levels will be the starting point for any site-specific permit, but will be reviewed as part of the site permitting process based on any additional information provided by a future UK EPR operator. The limits would also be reviewed periodically thereafter, as data becomes available from operational UK EPR reactors.
- 149 Note that the base case discharges for the UK EPR do not include any associated waste and spent fuel storage facilities, our limits do not include any allowance for possible gaseous disposals from these facilities.

Radionuclides or group of radionuclides	Proposed Annual limit GBq	Proposed Quarterly notification level GBq
Tritium	3000	200
Carbon-14	700	100
Noble gases	22500	2250
Iodine-131	0.4	0.04
All other radionuclides (excepting tritium, carbon-14, iodine radionuclides and noble gases)	0.05	0.027

- 150 We conclude that the UK EPR stack provides adequate dispersion under GDA generic site conditions. However dispersion is very location specific and will need to be demonstrated as adequate by modelling for each specific site.
- 151 As part of our assessment we identified the following assessment finding:
- a) Future operators shall, before the commissioning phase, provide an assessment to demonstrate that proposed operational controls on the fuel pool are BAT to minimise the discharge of tritium to air. (UK EPR-AF07)

## References

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<http://www.food.gov.uk/science/surveillance/radiosurv/rife/rife08/>

While every effort has been made to ensure the accuracy of the references listed in this report, their future availability cannot be guaranteed.

## Abbreviations

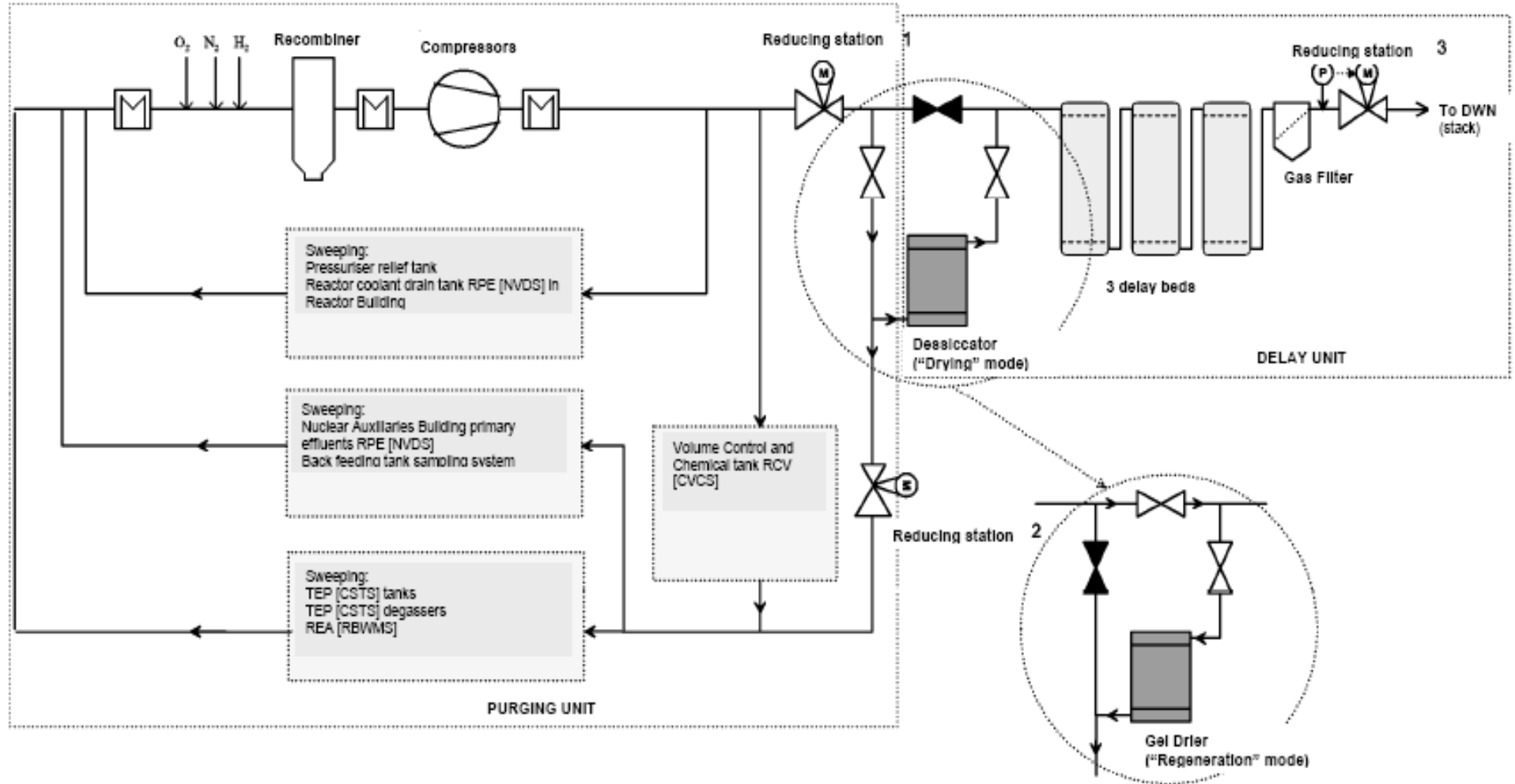
BAT	Best available techniques
C&I	Control and Instrumentation
CILWDS	Conventional island liquid waste discharge system
CSTS	Coolant Storage and Treatment System
CVCS	Chemical and Volume Control System
EAL	Environmental Assessment Level
EPR 10	Environmental Permitting (England and Wales) Regulations 2010
EPRB	GDA UK EPR – BAT demonstration, document UKEPR-0011-001
EPRB 3.5s1.2	EPRB form 3.3 section 1.2 (example reference)
FAPs	Fission and Activation Products
EWCPD	Established Worst Case Plant Discharges
GDA	Generic design assessment
GWPS	Gaseous Waste Processing System
HEPA	High efficiency particulate air
HLW	High level waste
HSE	Health and Safety Executive
HVAC	Heating, ventilation and air conditioning system
IWS	GDA UK EPR – Integrated Waste Strategy Document UKEPR-0010-001 Issue 00
JPO	Joint Programme Office
LWPS	Liquid Waste Processing System
NVDS	Nuclear Vent and Drain System
P&ID	Process and information document
ONR	<a href="#">Office for Nuclear Regulation, an Agency of the HSE (formerly HSE's Nuclear Directorate)</a>
PCER	Pre-Construction Environmental Report
PCERsc3.3s4.1	PCER sub-chapter 3.3 section 4.1 (example reference)
PCSR	Pre-Construction Safety Report
PPC	Pollution Prevention and Control
PWR	Pressurised water reactor
QNL	Quarterly Notification Level
RCS	Reactor Coolant System
REPs	Radioactive substances regulation environmental principles
RI	Regulatory Issue
RO	Regulatory Observation
RSA 93	Radioactive Substances Act 1993
SG	Steam Generator
TQ	Technical Query
VCT	Volume Control Tank
WCPD	Worst Case Annual Plant Discharges



## Annex 1: Figures from the PCER

PCERsc6.4s3 Figure 1

Section 3 FIGURE 1: SIMPLIFIED DIAGRAM OF THE TEG [GWPS] SYSTEM



PCERsc6.2s1.2.3.2 Figure 10

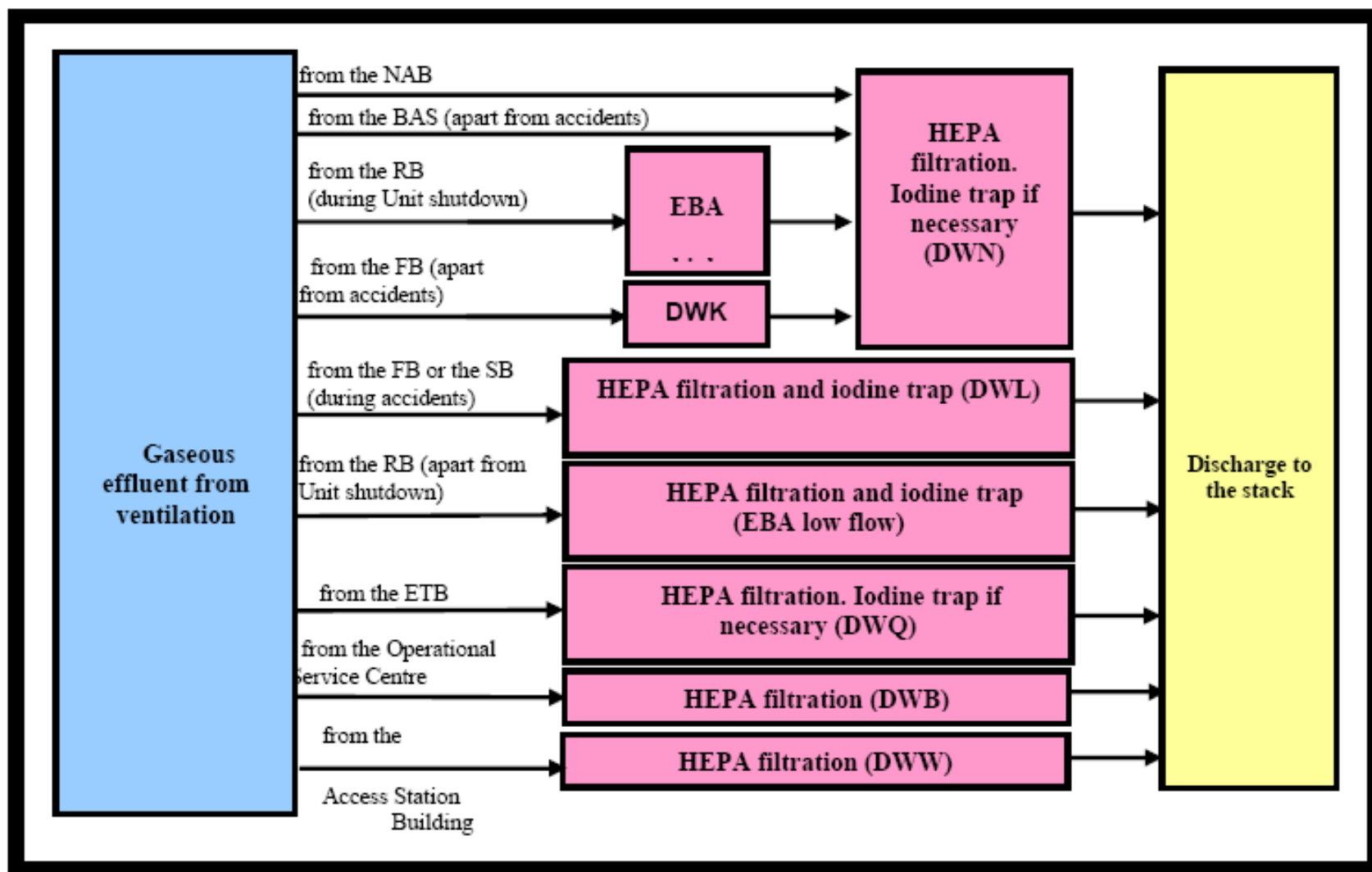


Figure 10: Treatment of gaseous effluent from ventilation

PCERsc6.3s7.4.1

### 7.4.1. Design characteristics

The Primary Gaseous Effluent Treatment System (TEG [GWPS], see Sub-Chapter 6.4) is from the Konvoi design: i.e. a semi-closed loop system for treatment of aerated effluent, which differs from the 1 300 MWe design. In particular, this design enables better treatment of peaks in activity when switching to cold shutdown. Its main characteristics are:

- Sharing of the TEP [CSTS] and REA [RBWMS] tank cover gas: this limits the volume of the gaseous waste in normal operation by maintaining a constant gas volume when transferring water,
- Continuous nitrogen flushing of the tank cover gas: this reduces the H<sub>2</sub> content, by standardising gas treatment irrespective of whether its composition contains H<sub>2</sub> or O<sub>2</sub>,
- Recycling of gases: this limits the volume of the gaseous waste in normal operation,
- Recombination of hydrogen (the potential dissolving in tritium and iodines has an uncertain effect and has therefore been rejected),
- Decaying the gasses (mainly Xenon and Krypton) on delay beds (activated charcoal tanks): This ensures 40 hours of decay for krypton and 40 d for xenon (half-life of 5.25 d for 133 Xe),
- Discharge via the stack as soon as a threshold pressure, which can be adjusted according to the volumes of gas to be treated, has been reached. This changes the system's storage capacity.

PCERsc6.3s7.4.3.1 Figure 16

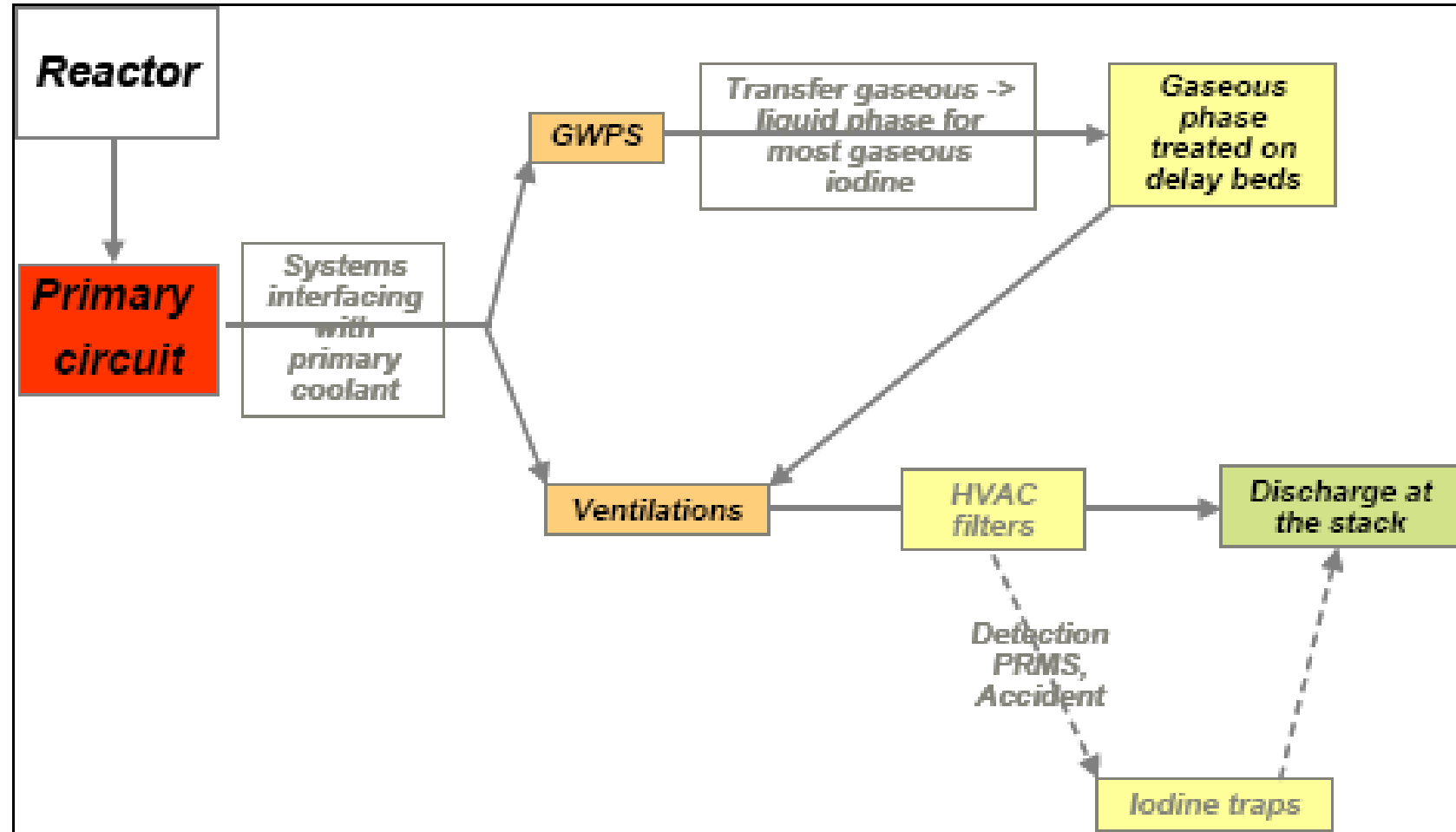


Figure 16: Gaseous iodine treatment system

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