Generic design assessment
UK EPR nuclear power plant design by AREVA NP SAS and Electricité de France SA

Assessment report
Best available techniques to prevent or minimise creation of radioactive wastes

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Published by:

Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506

Email: enquiries@environment-agency.gov.uk

www.environment-agency.gov.uk

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Assessment report – best available techniques to prevent or minimise the creation of radioactive waste

Protective status	This document contains no sensitive nuclear information or commercially confidential information.
Process and Information Document[1]	The following sections of Table 1 in our Process and Information document are relevant to this assessment: 1.5 – show that the best available techniques will be used to minimise the production of waste 2.1 – describe sources of radioactivity and matters which affect wastes arising
Radioactive Substances Regulation Environmental Principles[2]	The following principles are relevant to this assessment: RSMDP3 - Use of BAT to minimise waste
Report author	Roger Green

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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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1 Summary

1 This report presents the findings of our assessment of whether the best available techniques to prevent or minimise the creation of radioactive waste are used by the UK EPR, based on information submitted by EDF and AREVA in their Pre-Construction Environmental Report (PCER) and supporting documents.

2 We conclude that overall the UK EPR uses the best available techniques to prevent the unnecessary creation of radioactive waste and, where wastes are created, minimises the generation of those wastes.

3 However our conclusion is subject to four other issues, which will need to be addressed during site specific permitting.

4 Other issues:

a) Zinc injection as an option for the UK EPR to aid corrosion control.

b) Assessment of the removal of secondary neutron sources (to further minimise creation of tritium) when EPR operational information becomes available.

c) Review of the BAT assessment on the minimisation of the production of activated corrosion products for the following matters where possible improvements were identified in the PCER:

    i) corrosion resistance of steam generator tubes;

    ii) electro-polishing of steam generator channel heads;

    iii) specification of lower cobalt content reactor system construction materials;

    iv) further reducing use of stellites in reactor components, in particular the coolant pump;

    and incorporation of the improvements into the design where appropriate.

d) Provision of the design of the discharge tanks (LRMDS, ExLWDS and CILWDS tanks) with associated demonstration of BAT for size and leak-tight construction.

5 Our findings on the wider environmental impacts and waste management arrangements for the UK EPR reactor may be found in our Consultation Document (Environment Agency, 2010a).

2 Introduction

6 We require new nuclear power plant to be designed to use the best available techniques (BAT) to prevent the unnecessary creation of radioactive wastes. Where wastes are created we expect BAT to be used to minimise the generation of those wastes.

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

a) shows BAT will be used to minimise the production of waste (reference 1.5); and

b) describes sources of radioactivity and matters which affect wastes arising (reference 2.1).

8 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*."

9 In our Radioactive Substances Regulation Environmental Principles (REPs, see Environment Agency, 2010b), principle RSMDP3 (Use of BAT to minimise waste) refers to this topic:

> "*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.*"

10 In particular, a consideration under principle RSMDP3 is relevant:

> "*Processes creating radioactive materials should be chosen and optimised so as to prevent and where that is not practicable minimise the production of radioactive waste at source over the complete lifecycle of the facility*."

11 The methodology for identifying BAT is given in principle RSDMP4 and the application of BAT is described in principle RSDMP6. We also published in 2009 our Assessment Guide: "Radioactive Substances Regulation: Assessment of Best Available Techniques" (now Environment Agency, 2010c). The Guide says that, for initial clarity:

> "*BAT are the means by which an operator optimises the operation of a practice in order to reduce and keep exposures from the disposal of radioactive waste into the environment as low as reasonably achievable, economic and social factors being taken into consideration (ALARA)*".

12 In this report we assess the techniques EDF and AREVA use in the UK EPR to prevent or minimise the creation of waste at source, that is mainly in the reactor, and present our conclusions on whether BAT is demonstrated.

13 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".

14 EDF and AREVA completely revised their submission during 2008 and provided a Pre-Construction Environmental Report (PCER) with supporting documents.

15 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.

16 We raised 31 Technical Queries (TQs) on EDF and AREVA during our assessment. Two were relevant to this report:

a) Fuel management regimes and their impact on proposed liquid and gaseous radioactive waste discharges.

b) Discharge of actinides.

17 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. This report only uses and refers to the information contained in the updated PCER and its supporting documents.

3 Assessment

3.1 Assessment Methodology

18 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 prevent or minimise the creation of radioactive waste using our internal guidance and regulatory experience and decide if they represent BAT;

e) decide on any GDA Issues or other issues to carry forward from GDA.

3.2 Assessment Objectives

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

a) have all sources of radioactive waste been identified?

b) have the significant radionuclides present in waste been identified? These are those which contribute significantly to the amount of activity in waste disposals or to the potential doses to members of the public (see our Considerations document, Environment Agency, 2009).

c) have options for preventing and minimising the creation of significant radionuclides that will be present in waste been presented?

d) are the options chosen for the UK EPR BAT?

3.3 EDF and AREVA documentation

20 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	03
UKEPR-0003-012	PCER – Sub-chapter 1.2 – General description of the unit	01
UKEPR-0003-030	PCER – Chapter 3 – Aspects having a bearing on the environment during operation phase	02
UKEPR-0003-061	PCER – Sub-chapter 6.1 – Sources of radioactive materials	03
UKEPR-0003-062	PCER – Sub-chapter 6.2 – Details of the effluent management process	03
UKEPR-0003-063	PCER – Sub-chapter 6.3 – Outputs for the Operating Installation	03
UKEPR-0003-064	PCER – Sub-chapter 6.4 - Effluent and waste treatment systems design architecture	03

Document reference	Title	Version number
UKEPR-0003-080	PCER – Chapter 8 – Best Available Techniques	01
UKEPR-0003-110	PCER – Chapter 11 – Radiological impact assessment	02
UKEPR-0011-001	GDA UK EPR-BAT Demonstration	03
UKEPR-0010-001	GDA UK EPR – Integrated Waste Strategy Document	02

21 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.

3.4 UK EPR design and sources of radioactivity

22 The UK EPR design is for a single pressurised water reactor. In the reactor core, the uranium oxide fuel (enriched up to 5 percent of uranium-235) is cooled by water in a pressurised circuit, the primary circuit. This water also acts as the neutron moderator necessary for a sustained nuclear fission reaction. The fuel is contained in sealed fuel pins. 265 fuel pins are held together in a fuel assembly. The UK EPR contains 241 fuel assemblies, a total of 63,865 fuel pins.

23 Most radioactivity is associated with the fuel and its fission products and is retained within the fuel pin. This radioactivity is an unavoidable part of the nuclear power process and goes forward with spent fuel, see our assessment report EAGDAR UK EPR-07 (Environment Agency, 2010d).

24 The fuel pin cladding is designed to contain the fuel and its fission products. However any defect in the fuel cladding either from manufacture or produced during operation can release radioactivity into the reactor water coolant surrounding the pins. The most significant radioactivity is in the form of fission products such as:

a) noble gases, in particular xenon-133, xenon-135 and kyrpton-85;

b) iodine radionuclides, in particular iodine-131;

c) caesium-134 and caesium-137; and

d) strontium-89 and strontium-90.

25 Radioactive actinides (in particular plutonium, americium, curium and uranium) can also be found in the coolant resulting not only from fuel pin failures but also from any uranium contamination left on the surface of the fuel pins during manufacture (called tramp uranium).

26 The reactor coolant is essentially water but contains some chemicals such as:

a) boric acid to control the reactivity of the reactor (boron is a good neutron absorber);

b) lithium hydroxide to balance the pH of the coolant to offset the corrosive effect of boric acid;

c) dissolved nitrogen from contact of the coolant with air before use in the reactor and then with nitrogen used to pressurise vessels associated with the reactor system.

27 The components of the reactor system are made of various metals and alloys and are in contact with the reactor coolant. The chemicals in the coolant, particularly boric acid, can cause erosion and corrosion of the contacted surfaces and give both soluble and insoluble (particles) corrosion products.

28 Radionuclides can be produced by activation of the chemicals and corrosion products in the coolant as it passes through the reactor core. The most significant of these are:

a) tritium;
b) carbon-14;
c) cobalt-60 and cobalt-58.

29 Activation products can also be formed in structural reactor components, most of the radioactivity thus produced will remain within the components (a matter for decommissioning) but some can be released by corrosion and erosion to add to the activated corrosion products mentioned above.

30 Argon-41 can be formed by activation of the natural argon content of air in the vicinity of the reactor. It can be collected by ventilation systems – although the Reactor Building is not ventilated in normal operation – and discharged through the main stack. A small amount of argon-41 may also be produced from the argon in air dissolved in the reactor coolant - mostly after a shutdown.

31 The above summarises information in the PCERsc6.1 and sc6.3. We are content that EDF and AREVA have identified all the sources of radioactivity in the UK EPR.

32 Annex 4 of our main Consultation Document (Environment Agency, 2010a) gives a summary of the sources and types of radioactivity in PWRs.

3.5 Significant radionuclides in waste from the UK EPR

33 EDF and AREVA list all radionuclides that will be created in Table 2 of EPRBs2. The Table gives source terms, mechanism for creation and a ranking for significance as high, medium or low.

34 We agree with the EDF and AREVA methodology for assessing significance of radionuclides created based on:

a) half-life (indicator of whether impact is lasting);
b) magnitude of source term;
c) contribution to dose, EDF and AREVA have used >5% total dose as significant;
d) whether an indicator of plant performance.

35 EDF and AREVA identify the following radionuclides as having high significance:

a) Tritium
b) Carbon-14
c) Noble gases – a group containing Kr-85, Kr-85m, Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135, Xe-138
d) Iodine radionuclides – a group containing I-131, I-132, I-133, I-134, I-135
e) Cobalt-60 – Cobalt-58 to be included with Co-60 although of low significance.

36 EDF and AREVA carried forward the above radionuclides for detailed BAT options assessment to demonstrate that disposals are minimised by the UK EPR. They relied on information in EPRB Table 2 to demonstrate that the creation of less significant radionuclides had been minimised.

37 We accept that EDF and AREVA have identified the significant radionuclides for detailed BAT assessment. We will use those listed at paragraph 34 above as the basis for our disposal limits although we will need to consider the total of activation products rather than just Co-60. We assess below whether BAT has been used by the UK EPR to minimise the creation of the less significant radionuclides.

3.6 Assessment of BAT for creation of less significant radionuclides

38 We summarise information from EPRB Table 2 (in the same order) and provide our assessment. Predicted discharges relate to discharges to water, except for Ar-41 which is discharged to air.

3.6.1 Ag-110m (Silver-110m)

39 Ag-110m is an activated corrosion product from the activation of normal silver-109 contained in control rods and helicoflex seals. EDF and AREVA state that for the UK EPR:

a) the use of helicoflex seals will be reduced in favour of graphite seals; but

b) control rods cannot be modified.

40 The filter and ion exchange system in the liquid waste processing system will also be effective in minimising final disposal.

41 The predicted discharge of Ag-110m is 34 MBq y^{-1} (5.7% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life is 250 days so it will not persist in the environment.

42 The predicted discharge is sufficiently low that we agree that reducing use of helicoflex seals is sufficient to demonstrate BAT and that modification of control rods is not required.

3.6.2 Ar-41 (Argon-41)

43 Ar-41 can be formed by activation of the natural argon content of air in the vicinity of the reactor. It can be collected by ventilation systems – although the Reactor Building is not ventilated in normal operation – and discharged through the main stack. EDF and AREVA say there are no practicable means to prevent or minimise the creation of Ar-41.

44 A small amount of Ar-41 may also be produced from the argon in air dissolved in the reactor coolant - mostly after a shutdown. (PCERsc6.1s2.4)

45 PCERsc6.3s7.4.2.1 indicates that Ar-41 will form 2.9% of the “expected performance” of noble gas discharges i.e. 23.2 GBq y^{-1}. The discharge of Ar-41 should not increase when discharges of noble gases increase in the event of any fuel defects. However EDF and AREVA chose to use a discharge value of 2.9% of the “maximum” for noble gases (653 GBq Ar-41) to predict a pessimistic impact for Ar-41. The radiological impact from the disposal of Ar-41 to air is stated as a dose to adults of 0.014 µSv y^{-1}, to children of 0.0083 µSv y^{-1} and infants of 0.0065 µSv y^{-1} – from PCERsc11.1 Annex 3 Tables B, C and D.

46 The half-life of Ar-41 is under 2 hours and the UK EPR discharge has little environmental impact, 0.0005 µSv y^{-1} to an adult at the “expected performance” discharge. Ar-41 discharges from PWRs are less than 1% of those from the UK AGRs and less than 0.1% of those from Magnox reactors.

47 We accept there are no means to prevent creation of Ar-41. The predicted impact of Ar-41 is sufficiently low that we accept that it is not proportionate to assess BAT in detail for Ar-41 discharge. But its discharge will be monitored and counted with the other noble gases at the main stack.

3.6.3 Cr-51 (Chromium-51)

48 Chromium-51 is an activated corrosion product from activation of normal chromium-50, a part of stainless steels used in structural components of the reactor system. EDF

and AREVA say materials are specified to limit the source but chromium is an essential part of stainless steels, prevention or minimisation is not practicable.

49 Corrosion prevention measures are employed in the UK EPR (see 3.7.4 below) that should minimise the quantity of corrosion products. Also the filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal.

50 The predicted discharge of Cr-51 is <3.6 MBq y^{-1} (<0.6% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life is 28 days so it will not persist in the environment.

51 The predicted discharge is sufficiently low that we agree that it is not proportionate to assess BAT further for Cr-51 discharge.

3.6.4 Cs-134 (Caesium-134) also Cs-136, Cs-137, Cs-138

52 Caesium-134, Cs-136, Cs-137 and Cs-138 are fission products normally contained within the fuel cladding. If there are any fuel defects caesium can pass into the primary reactor coolant. They can also be formed on the surface of fuel pins if any trace uranium contamination is left from manufacture (tramp uranium).

53 Creation of fission products cannot be prevented. EDF and AREVA claim the quantity of fission products is minimised as the UK EPR reduces fuel use against energy production by use of a large core, a neutron reflector and increased overall thermal efficiency.

54 We accept that caesium production cannot be prevented at source but should be contained. We assess the integrity of the fuel cladding and the matter of tramp uranium under noble gases. We accept that the UK EPR design uses fuel more efficiently than predecessor designs and should produce less fission products and that these should be retained by the fuel cladding.

55 Caesium is highly soluble and, if released from the fuel, the filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal. The detection of caesium in liquid radioactive waste disposals is an indicator of fuel integrity.

56 The predicted discharge of Cs-134 is 34 MBq y^{-1} and of Cs-137 is 57 MBq y^{-1} (5.6% and 9.45% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). The half-life of Cs-134 is 2 years and of Cs-137 30 years so they will persist in the environment. The half life of Cs-136 is 13 days and of Cs-138 is 32 minutes, EDF and AREVA claim they have no significant contribution to dose.

57 The predicted discharge is sufficiently low that we agree that it is not proportionate to assess BAT in further detail for caesium discharges. However as an indicator of fuel integrity we will consider a specific aqueous disposal limit, otherwise caesium radionuclides will be counted in a total disposal limit.

3.6.5 Fe-59 (Iron-59)

58 Iron-59 is an activated corrosion product from the activation of the normal iron-58 content of all metallic materials used in the reactor system. The use of iron is unavoidable, prevention or minimisation is not practicable.

59 The filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal.

60 The predicted discharge of Fe-59 is <3.6 MBq y^{-1} (<0.6% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life is 45 days so it will not persist in the environment.

61 The predicted discharge is sufficiently low that we agree that it is not proportionate to assess BAT for Fe-59 discharge.

3.6.6 Mn-54 (Manganese-54)

62 Manganese-54 is an activated corrosion product from the activation of the normal iron-54 content of all metallic materials used in the reactor system, no minimisation is practicable. The use of iron is unavoidable, prevention or minimisation is not practicable.

63 The filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal.

64 The predicted discharge of Fe-59 is 16 MBq y^{-1} (2.7% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life is 313 days so it will have limited persistence in the environment.

65 The predicted discharge is sufficiently low that we agree that it is not proportionate to assess BAT for Mn-54 discharge.

3.6.7 N-16 and N-17 (Nitrogen-16 and Nitrogen-17)

66 Nitrogen-16 and -17 are produced by the activation of normal oxygen-16 and -17 present in the dissolved air and other chemicals in the reactor coolant. There is no practicable way to reduce their formation.

67 However, their short half-lives, 7.3 and 4.2 seconds, mean that discharges to the environment will be insignificant. We agree that EDF and AREVA do not need to consider further for minimisation. We will not consider them further in our assessment, note, however, that they are significant for operator dose.

3.6.8 Ni-63 (Nickel-63)

68 Nickel-63 is an activated corrosion product from activation of normal nickel-62 present in structural materials, in particular Alloy 690 used in the steam generator tubes. EDF and AREVA claim the use of nickel alloys is unavoidable, prevention or minimisation is not practicable.

69 Corrosion prevention measures are employed in the UK EPR (see 3.7.4 below) that should minimise the quantity of corrosion products. Also the filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal.

70 The predicted discharge of Ni-63 is 58 MBq y^{-1} (9.6% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life is 100 years so it will persist in the environment.

71 The predicted discharge is sufficiently low that we agree that it is not proportionate to assess BAT further for Ni-63 discharge.

3.6.9 Sb-122 and Sb-124 (Antimony-122 and Antimony-124)

72 Antimony-122 and -124 are activated corrosion products from the activation of other normal antimony isotopes used a base for alloys used in some seals and pump bearings. EDF and AREVA state that the UK EPR will:

a) reduce the use of helicoflex seals containing antimony in favour of graphite seals;

b) make greater use of rotor stops and bearings without antimony.

73 The filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal.

74 The predicted discharge of Sb-124 is 29 MBq y^{-1} and of Sb-122 is <3.6 MBq y^{-1} (4.9% or <0.6% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life of Sb-124 is 60 days so it has low persistence in the environment, half-life of Sb-122 is 2.7 days so persistence is very low.

75 The predicted discharge is sufficiently low that we agree that the use of the two techniques noted above to minimise creation of Sb-122 and Sb-124 is BAT and it is not proportionate to assess BAT further for these discharges.

3.6.10 Sb-125 (Antimony-125)

76 Antimony-125 is a further activation product from the activation of antimony-124 produced as described above. This will be reduced as the production of antimony-124 is reduced as described in section 3.6.9 above.

77 The filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal.

78 The predicted discharge of Sb-125 is 49 MBq y^{-1} (8.15% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life of Sb-125 is 2.73 years so it will persist in the environment.

79 The predicted discharge is sufficiently low that we agree that the use of the two techniques noted above to minimise creation of Sb-124 is also BAT for the creation of Sb-125 and it is not proportionate to assess BAT further for Sb-125.

3.6.11 Sr-89 and Sr-90 (Strontium-89 and Strontium-90)

80 Strontium-89 and -90 are fission products normally contained within the fuel cladding. If there are any fuel defects strontium can pass into the primary reactor coolant but strontium is considered less mobile than caesium. They can also be formed on the surface of fuel pins if any trace uranium contamination is left from manufacture (tramp uranium).

81 Creation of fission products cannot be prevented. EDF and AREVA claim the quantity of fission products is minimised as the UK EPR reduces fuel use against energy production by use of a large core, a neutron reflector and increased overall thermal efficiency.

82 We accept that strontium production cannot be prevented at source but should be contained. We assess the integrity of the cladding and matter of tramp uranium under noble gases. We accept that the UK EPR design uses fuel more efficiently than predecessor designs and should produce less fission products and that these should be retained by the fuel cladding.

83 The filter and ion exchange system in the liquid waste processing system will be effective in minimising final disposal.

84 The predicted discharge of Sr-89 and Sr-90 together are <3.6 MBq y^{-1} (if taken as “Others” - 0.6% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15) however, EDF and AREVA claim that strontium cannot be detected in releases from currently operating nuclear power plants in France. (PCERsc8.4s5.1). The half-life of Sr-89 is 50 days and of Sr-90 is 29.2 years so Sr-90 will persist in the environment.

85 The predicted discharge is sufficiently low that we agree that it is not proportionate to assess BAT in detail for strontium discharges.

3.7 Assessment of BAT for creation of significant radionuclides

86 EDF and AREVA identified the following radionuclides or groups of radionuclides that were significant in radioactive waste produced by the UK EPR (see section 3.4 above):

a) Tritium

b) Carbon-14

c) Noble gases

d) Iodine radionuclides

e) Cobalt-60 / cobalt-58

87 EDF and AREVA provided a detailed BAT assessment for each of these radionuclides from creation to disposal in the EPRB (BAT Forms). We summarise below the information in the BAT Forms and PCER on minimising creation and provide our assessment.

3.7.1 Carbon-14 (EPRBs3.2)

88 Carbon-14 is produced mainly by 2 mechanisms within the reactor coolant (PCERsc6.3s6.3.1, PCERsc6.3sc7.3.1 and EPRBs3.2):

a) activation of oxygen-17 (O-17(n,α)→C-14), a naturally occurring stable isotope of oxygen as part of the water molecules making up the reactor coolant and within chemicals contained in the coolant such as boric acid and lithium hydroxide. The annual production of C-14 from O-17 is calculated as 401 GBq. There is no practicable way to avoid this formation route.

b) activation of nitrogen-14 (N-14(n,p)→C-14). Nitrogen is used as a cover gas in the system that treats reactor coolant and to control pressure in the Volume Control Tank, a certain portion will dissolve in the coolant. The annual production of C-14 from N-14 is dependent on the dissolved concentration of nitrogen, calculations presented by EDF and AREVA predict 43 GBq at 10 ppm (expected) to 219 GBq at 52 ppm (extreme maximum). EDF and AREVA claim using nitrogen as a cover gas (as used in the predecessor KONVOI design) is a safety feature instead of hydrogen as it reduces risk of hydrogen / air combustion. This offsets the possible 10 - 50% increase in C-14 production.

89 EDF and AREVA use 440 GBq y^{-1} as their base value for production of C-14. We accept that there are no techniques that can be used to minimise production of C-14 from O-17. Management of operational dissolved nitrogen levels is critical to minimise production of C-14 from N-14, this will be reflected in our disposal limits. The half-life of C-14 is 5730 years so it will be persistent in the environment. The level of production and the long half-life make C-14 the most significant radionuclide discharged.

90 Other minor mechanisms contribute to C-14 discharge:

a) a trace of dissolved carbon can be present in the coolant – this can be activated to C-14 (C-13(n,γ)→C-14) (PCER6.3s6.3.1.1);

b) nitrogen impurities and oxygen within the fuel can be activated to C-14 but the C-14 will normally be contained within the fuel cladding (EPRBs3.2);

c) the “aeroball” system used to measure neutron flux within the reactor is driven by nitrogen, the nitrogen can be activated to C-14 but production estimates give a maximum of 1.5 GBq y^{-1} (PCERsc6.3s7.3.1.1);

d) the air within the reactor pit contains oxygen and nitrogen that can be activated to C-14, the maximum production is estimated as 1 GBq y^{-1} (PCERsc6.3s7.3.1.2).

We do not consider it necessary or proportionate to assess BAT for these sources as they represent less than 1% of the total C-14 discharge.

91 We conclude that BAT is used by the UK EPR to minimise production of carbon-14 provided that dissolved nitrogen levels are managed. We will use 10 ppm as a basis for disposal limit setting with contingencies for higher levels.

3.7.2 Tritium (EPRBs3.3)

92 Tritium is produced by 3 main mechanisms and initially contained within the reactor coolant (see PCERsc6.2s1.2.1, PCERsc6.3s6.2.1 and EPRBs3.3):

a) activation of boron (present as boric acid)(B-10$(n,2\alpha)\rightarrow$H-3 or B-10$(n,\alpha)\rightarrow$Li-7$(n,\alpha n)\rightarrow$H-3) in the reactor coolant. Boron (in particular the isotope boron-10 making up 20% of natural boron) is used to control the reactivity of the reactor. The UK EPR uses boric acid with the boron-10 content enriched to 37%. EDF and AREVA claim that the quantity of boron needed in the reactor coolant has been reduced in the UK EPR by the use of a burnable poison – gadolinium oxide – within some of the fuel. They claim this has reduced the production of tritium by the UK EPR from this source compared to predecessor reactors despite an increase in power but they do not quantify the reduction as this is dependent on the fuel management approach adopted.

b) activation of the lithium-6 content (Li-6$(n,\alpha)\rightarrow$H-3)(approximately 7.5% of natural lithium) of the lithium hydroxide used for chemical pH control of the reactor coolant to offset the corrosive effect of boric acid. Lithium-7 can also be activated (Li-7$(n,\alpha n)\rightarrow$H-3) but has a very low thermal neutron absorption cross-section of 37 millibarns compared to Li-6 with 953 barns. The amount of boric acid needed has been reduced by the use of a burnable poison – see above – and also by using boric acid with an enriched boron-10 (the important neutron absorber) content. This reduces the quantity of lithium hydroxide needed. The UK EPR will also use hydroxide containing less than 0.1% lithium-6 to reduce tritium production. EDF and AREVA state that with natural lithium, tritium production would be 1-2 TBq day^{-1} but do not quantify the reduction use of the low lithium-6 hydroxide will achieve. However their total “expected performance” disposals equate to less than 0.16 TBq day^{-1}.

c) activation of beryllium (initially to lithium-6 then to tritium)(Be-9$(n,\alpha)\rightarrow$Li-6$(n,\alpha)\rightarrow$H-3) in the secondary neutron sources. These antimony / beryllium sources are used to demonstrate the function of neutron measurement equipment, an essential safety feature for plant start-up, and are cased in stainless steel that is permeable to tritium. The PCER states that production from this source is 9 TBq y^{-1}. The EPRB and the PCER discuss options to remove these sources or to use an impermeable zirconium-based alloy for the cladding:

   i) information from an operational EPR is needed before removal can be assessed.

   ii) a change in cladding is discarded as this would:

      a) be a departure from a proven design; and

      b) require more frequent change of sources giving possible additional operator exposure to radioactivity and generating more solid waste.

   iii) a further option would be to use alternative neutron producing sources but EDF and AREVA do not believe such are currently available. We will not pursue this option at present but will note for future reviews if removal of the sources proves unsafe.

93 The production of tritium (excluding the contribution from the secondary neutron sources) is directly related to power output of the reactor. EDF and AREVA claim that

the above measures mean that the UK EPR will produce only 4% more tritium than the predecessor 1300 MWe reactor while its power output is some 25% greater. The predicted production rate is 52 TBq y^{-1}. The majority of tritium produced will be in the form of tritiated water. Tritium has a half-life of 12.33 years so will persist in the environment. However tritium is a very low energy beta emitter with low impact to humans, so while quantity and half-life of tritium are significant the impact of the discharges from the UK EPR are not as significant as C-14.

94 We accept that the above techniques demonstrate that BAT is used by the UK EPR to minimise production of tritium from the activation of boron and lithium. For the secondary sources:

a) we accept that a cladding change should not be pursued;

b) we expect EDF and AREVA to pursue assessment of removing these sources and present information when available during specific site permitting.

95 There are some other sources of tritium:

a) activation of deuterium in the reactor coolant (deuterium, also know as heavy hydrogen as its nucleus contains a neutron and a proton while hydrogen contains only a proton, is naturally present in water at 0.015%). EDF and AREVA claim that while a technique, isotopic separation, is available to reduce the deuterium content of water it is not practicable for use due to the large volumes of water used. Also the production by this route is relatively small so benefit would be limited. We accept isotopic separation is not BAT at this time;

b) ternary fission products, normally contained within the fuel cladding;

c) activation of helium pressurising the fuel pins, normally contained within the fuel cladding.

96 More information on these sources is presented in the PCERsc6.3s6.2.1.2. We do not consider these sources are significant as regards discharges. We have not specifically assessed BAT for these sources but activation of deuterium is unavoidable and fuel cladding integrity is assessed below under noble gases.

97 We conclude that EDF and AREVA have demonstrated that BAT is used to minimise the production of tritium in the UK EPR at this time, bearing in mind the low significance of its impact. However we do require them to consider removal of the secondary neutron sources as soon as operational experience is available to evaluate any safety risks associated with this change.

3.7.3 Cobalt-58 and Cobalt-60 (EPRBs3.4)

98 EDF and AREVA use Co-58 and Co-60 as the most significant examples of activated corrosion products and provide a detailed BAT assessment for them. They provide a useful introduction to the topic (EPRBs3.4ss1.1):

> '*The presence of corrosion products in the primary coolant is the result of complex processes, which involve interacting physical and chemical mechanisms on in-core reactor materials. Contact between primary circuit materials with water at high temperature causes the uniform and global corrosion of the metallic components of the primary circuit. It produces an oxide layer on in-core surfaces, especially on the surfaces of the steam generator tubes. Corrosion products are released or dissolved as ions in the coolant water, some of which attach themselves to particulate material or remain in solution. When the primary coolant is saturated with ions, these particles are formed and can either be deposited on the surface of the circuit, or liberated by erosion of deposits. Those corrosion products are transported in the primary coolant and, when they set in or pass through the core area, they become activated by the neutron flux.*

> *Activated products can also be released in the primary circuit by corrosion and erosion of activated structural reactor components'.*

99 Cobalt-58 is an activated corrosion product from the activation of normal nickel-58 (Ni-58(n,p)→Co-58), a major constituent of nickel based alloys (e.g. Alloy 690 used in the Steam Generator tubes) and of the stainless steel used in reactor materials.

100 EDF and AREVA say they are evaluating:

a) improvements to the corrosion resistance of steam generator (SG) tubes (PCERsc8.2s3.3.1.1.3); and

b) polishing of SG channel heads to reduce erosion and corrosion potential (PCERsc8.2s3.3.1.1.5).

101 The above options would reduce nickel-58 corrosion products entering the coolant. We will require EDF and AREVA to provide their BAT cases for these options at the site specific permitting stage.

102 Cobalt-60 is an activated corrosion product from the activation of normal cobalt-59 (Co-59(n,γ)→Co-60). Co-59 can also be formed by deactivation of Co-58 (Co-58(n,γ)→Co-59). Co-59 is a major constituent of steels and, in particular, "hard" high cobalt alloys (stellites) used in valve seats etc. Wear of stellite-coated surfaces can give particles that are carried by the coolant into the reactor core where their Co-59 content becomes activated.

103 EDF and AREVA propose to minimise the amount of cobalt in contact with the reactor coolant in the UK EPR (PCERsc8.2s3.3.1.1.1 and EPRBs3.4):

a) by excluding stellites from valves used in the reactor coolant systems. This is estimated to reduce the total dose predicted for the UK EPR by 8%.

b) by reducing the use of stellites in other reactor components. But the programme is not complete, EDF and AREVA say development work is ongoing, for example that stellites parts of reactor coolant pumps to be assessed". (PCERsc8.2s3.3.1.1.1)

c) EDF and AREVA say they are making "constant improvements" to specify low cobalt contents of stainless steels, welding materials and steam generator tubing. (EPRBs3.4ss3.1.2)

104 We require an update to the BAT case to show cobalt use has been minimised for the UK EPR to be built.

105 The predicted discharge of Co-58 is 124 MBq y^{-1} and of Co-60 is 180 MBq y^{-1} (20.7% and 30% of total discharge of fission and activation products 0.6 GBq y^{-1} – PCERsc6.3s6.4.2.1 Table 15). Half-life of Co-58 is 71 days and of Co-60 5.27 years, so Co-60 will persist in the environment and has high specific impact to humans so is a significant radionuclide in discharges.

106 We conclude that overall that the UK EPR uses BAT to minimise the creation of Co-58 and Co-60 however there are areas where improvement may be possible:

a) improvements to the corrosion resistance of steam generator (SG) tubes;

b) polishing of SG channel heads to reduce erosion and corrosion potential;

c) by further reducing the use of stellites in reactor components such as coolant pumps;

d) specifying lower cobalt contents of stainless steels, welding materials and steam generator tubing.

3.7.4 Control of corrosion

107 The reduction of corrosion is important to reduce the level of corrosion products. EDF and AREVA state that the UK EPR will:

a) use a programme to produce an oxide layer on reactor circuit components by exposing reactor circuit to demineralised water at high temperatures for a prolonged period in alkaline and reducing conditions before beginning power operation. This layer reduces the potential for corrosion products to form (PCERsc8.2s3.3.1.1.4).

b) apply a reactor chemistry regime to minimise formation of corrosion products based on the EDF PWR operational experience in France and EPRI guidance (PCERsc8.2s3.3.1.2 and EPRBs3.4ss3.2).

108 We accept the corrosion reduction techniques proposed as BAT but note control of chemistry during operation is the Operator's responsibility and should be continually optimised for minimum corrosion.

109 EDF and AREVA present some information on the use of zinc injection to control corrosion – PCERsc8.2s3.3.12.1.2. We received additional information on this topic too late to assess for the consultation, also the HSE has ongoing assessment in this area. We have therefore identified this as an 'other issue' at this time.

3.7.5 Noble gases (EPRBs3.5)

110 Noble Gases – a range of xenon and krypton radionuclides that are fission products produced by the burn-up of the uranium in the fuel:

Noble Gas	Half-Life	% of discharge
Krypton-85m (Kr-85m)	4.48 hours	
Krypton-85 (Kr-85)	10.72 years	13.9
Krytpton-87 (Kr-85)	1.27 hours	
Krypton-88 (Kr-88)	2.84 hours	
Xenon-131m (Xe-131m)	11.9 days	0.3
Xenon-133m (Xe-133m)	2.19 days	
Xenon-133 (Xe-133)	5.25 days	63.1
Xenon-135 (Xe-135)	9.09 hours	19.8
Xenon-138 (Xe-138)	14.2 minutes	

111 EDF and AREVA say Xe-133 is the most significant, followed by Xe-135 and Kr-85. Most half-lives, with the exception of Kr-85 are short and will have no long term radiological impact.

112 These noble gas radionuclides are normally contained within the fuel cladding. If there are any fuel defects these gases can pass into the primary reactor coolant. (EPRBs3.5)

113 Traces of uranium contamination can occur on new fuel assemblies (known as "tramp uranium") and its fission can also contribute to the presence of noble gas radionuclides in the coolant. EDF and AREVA claim fuel is "manufactured to stringent specifications and is subject to rigorous inspection". They claim that "tramp uranium" cannot be totally avoided but is only present in trace amounts. (EPRBs3.5ss3)

114 In normal operation, a portion of the coolant is passed through the Chemical and Volume Control System (CVCS). If removal of dissolved noble gases from the coolant is required the CVCS sends the coolant through a degasification system where gases are removed and sent to the Gaseous Waste Processing System (GWPS). The GWPS vents to the main stack. The level of noble gases at the main stack is a reflection of the failure of fuel cladding. (PCERsc6.3s7.4.2.1)

115 EDF and AREVA claim that the amount of fission products reaching the coolant through fuel defects can be minimised at source by "*high standards of fuel design and fabrication*". For example, there is "*clear separation between the "controlled" areas where pellets are manufactured and introduced in the cladding tubes which are the decontaminated before sealing and the "non-controlled" areas in which only sealed rods are handled. The surface contamination level is then checked for each fuel assembly".* They claim there will only be a small number of pins with minute defects (the "failed fuel fraction").

116 They claim that AREVA's PWR assemblies have "*exhibited consistently high operational reliability with an average annual fuel failure rate of approximately* 10^{-5}" and that this rate is "*less than half of the failure rate at the end of the 1980s*". The failure rate is the ratio of number of failed fuel pins discharged divided by the number of fuel pins in reactors which have been refuelled during the considered year, 10^{-5} means 10 in a million. (EPRBs3.5ss1.1 and PCERsc6.1s6.1.2)

117 EDF and AREVA state that the most common causes of fuel failures in operation are grid-to-rod fretting, corrosion and crud, debris, pellet cladding interaction and manufacturing upsets. They participate and contribute in the EPRI (Electric Power Research Institute – an independent USA organisation) Fuel Reliability Action Plan[1]. The UK EPR design minimises such failures by: (EPRBs3.5ss1.1)

a) Minimising initial surface contamination of fuel by best practice in manufacture;

b) Minimising crud formation by control of primary circuit chemistry;

c) Defining appropriate criteria for fuel design to prevent cladding failure;

d) Incorporating an efficient anti-debris device in the fuel assemblies.

118 EDF and AREVA say that any leaking fuel pins will be identified during refuelling and not reused. (EPRBs3.5ss3)

119 There are no techniques to prevent the production of xenon and krypton radionuclides within the fuel pins as they are fission products, their production is related to power output. The main factor in minimising discharges of noble gases is the reliability of fuel.

120 **We conclude that the average fuel failure rate quoted by EDF and AREVA is indicative of use of BAT to minimise the release of noble gases from the fuel in the UK EPR. Fuel integrity will be reflected in the disposal limits we set for noble gases.**

3.7.6 Iodine radionuclides (EPRB3.6)

121 Iodine radionuclides are fission products produced by the burn-up of the uranium in the fuel:

Iodine radionuclide	Half-Life
Iodine-131 (I-131)	8.04 days
Iodine-132 (I-132)	2.3 hours
Iodine-133 (I-133)	20.8 hours
Iodine-134 (I-134)	52.6 minutes
Iodine-135 (I-135)	6.61 hours

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[1] See http://my.epri.com/portal/server.pt?open=512&objID=242&PageID=367&cached=true&mode=2

122 I-131 is the most significant iodine radionuclide as it is has the longest half-life and is both a beta and gamma emitter and contributes most to dose.

123 Iodine radionuclides can appear in the coolant by 2 processes, as with noble gases:

a) through fuel leaks;

b) from “tramp uranium”.

124 We accept there are no techniques to prevent the creation of iodine radionuclides in the fuel pins. Minimisation of iodine radionuclides in the disposals relies on the integrity of fuel pins and control of tramp uranium. Both of these matters are covered above under noble gases.

125 We conclude that the UK EPR uses BAT to minimise the creation of iodine radionuclides for disposal, subject to the fuel failure quoted above being maintained.

3.7.7 Actinides

126 Radioactive actinides (in particular plutonium, americium, curium and uranium) are formed by a series of activations of uranium (PCERsc6.1s6.1.2):

a) in the fuel but will only appear in the coolant if there are fuel defects;

b) in any trace surface contamination of the fuel pins by fuel (called tramp uranium);

c) in impurities in the fuel cladding and in other materials.

They are potentially significant to the impact of disposals as they are alpha emitters.

127 EDF and AREVA claim that the sources of actinides from surface contamination or impurities are not significant compared to the potential for release through fuel defects.

128 EDF and AREVA claim that improvements in fuel reliability through design and quality manufacture minimise fuel leaks and hence the potential for actinide discharges. They also claim high removal efficiencies for actinide particulates in the filters in the Coolant Purification System of the Chemical and Volume Control System.

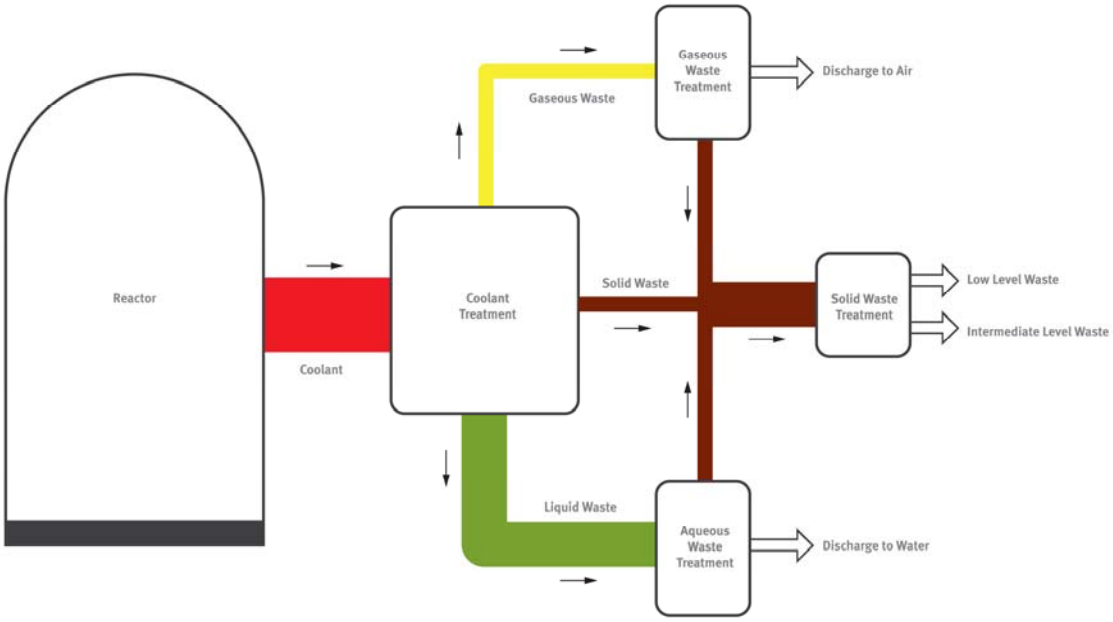
129 EDF and AREVA showed us an internal report examining data about alpha emitters in a number of operating plants with cladding defects. The report confirms the high removal efficiencies claimed. EDF and AREVA claim that their operational experience shows that even with fuel defects they have not been able to detect alpha emitters at the points of discharge for predecessor plants to the UK EPR. They will install alpha detectors (to give an alarm at level of detection) on both gaseous and aqueous discharge points but otherwise do not provide discharge estimates and do not consider disposal limits are required.

130 **We conclude that radioactive actinides will not contribute significantly to discharges or dose impacts. We do not consider it proportionate to assess actinides in detail and will not consider them in limit setting. The presence of actinides in discharges will be detected by the various monitoring arrangements.**

3.8 Processing of radioactive materials in the UK EPR

131 This section covers our assessment of how radioactive materials are processed and handled in the UK EPR. While this is a stage after waste creation we have included in this report as it defines whether wastes go to solid, gaseous or aqueous routes. We expect the processing options chosen for a new nuclear power plant to be those that will minimise the overall impact of their discharges on people and the environment. (Statutory Guidance (DECC 2009) and our REPS (Environment Agency 2010b) RSMDP7)

132 The majority of radioactive materials that will form waste are initially contained within the reactor coolant. Therefore the options employed to treat coolant are important factors that determine the form of radioactive waste and its ultimate disposal to solid, liquid and gaseous waste routes. We have illustrated flow paths for wastes in the diagram below:



133 The ventilation of controlled areas within the UK EPR to reduce worker exposure to radioactivity will contribute to gaseous discharges.

3.8.1 Primary circuit – the reactor coolant system (RCS)

134 The reactor coolant system (the RCS) includes the reactor, four steam generators and a pressuriser and contains the coolant. The coolant is essentially water with certain chemicals added for control purposes. To maintain this control a small flow of coolant from the RCS is sent to the Chemical and Volume Control System (CVCS). The CVCS purifies and degasifies the coolant and then adjusts chemistry by adding or removing chemicals, in particular boron. The coolant is pumped back into the RCS at a rate to maintain the contained volume. (PCERsc1.2s4.2.8)(Flow diagram - PCSRsc9.3s9.3.2 Figure 1)

135 The Coolant Purification System (CPS) takes coolant from the CVCS and passes it through a filter to remove suspended solid particles and demineralisers (ion exchange resins) to remove soluble metal compounds. The filter will remove 99.9% of particles sized at 1 micron or above. The CPS removes material that could be made radioactive by activation and also material that has been activated thus minimising radioactivity in the coolant, important both for radiation protection of workers and to minimise activity in aqueous radioactive waste produced. EDF and AREVA claim that use of filters below 1 micron adds to generation of solid waste (spent filter cartridges) for minimal reduction in the radioactivity of the coolant. The filter elements and spent demineraliser resins need to be replaced at intervals and become solid radioactive wastes that are usually Intermediate Level Waste (ILW). We consider use of filters and demineralisers in this system in the UK EPR is BAT to minimise discharges to the environment and is consistent with the principle of “concentrate and contain”. (EPRBs3.4)Flow diagram – PCSRsc9.3s9.3.2 Figure 2)

136 Coolant from the CVCS can be sent to a degasifier if required. This is mainly used before a shut-down or if noble gases are detected (loss of fuel integrity) in the coolant during operation. The gases removed from the coolant are sent to the Gaseous Waste Processing System (GWPS). The gases need to be removed to avoid build-up of radioactivity in the coolant both for radiation protection of workers and to avoid a surge in discharged activity at shut-downs. We consider availability of the degasifier and the GWPS in the UK EPR as BAT to control the radioactivity of gaseous wastes and minimise peaks of discharge. (PCERsc6.2s1.2.2.1)(Flow diagram - PCERsc9.3s9.3.3 Figure 3)

137 The CVCS can send coolant to the Reactor Boron and Water Makeup System (RBWMS). The boron concentration in the coolant is used to control reactivity in the reactor and is generally reduced over a power cycle (the time before refuelling – usually 18 months for the UK EPR). The RBWMS contains an evaporator that separates coolant into water that can be recycled back into the RCS and a boron concentrate that can be reused. We accept that the RBWMS within the UK EPR is BAT as recycling and reuse of water and boron will minimise the generation of aqueous waste. (PCERsc6.2s2.2.2.5)(Flow diagram – PCSRsc9.3s9.3.3 Figure 2 and PCSRsc9.3s9.3.4 Figure 1)

138 A Coolant Storage and Treatment System (CSTS) is associated with the CVCS. This contains 6 tanks that can store water and boron solution for use in the RCS. The tanks assist reuse and recycling accepting input from the RBWMS and the Nuclear Drain System. There is a route to bleed coolant to the LWPS when necessary to control tritium and carbon-14 content. Coolant volume can be made-up by adding demineralised water. Water is passed through a demineraliser and filter before transfer to the RCS by the CVCS. We consider that the UK EPR uses BAT to reuse and recycle liquids where possible to reduce liquid effluent volume. (PCERsc6.2s1.1.2.1)(Flow diagram – PCSRsc9.3s9.3.3 Figure 1)

139 The degree of recycling of effluents in the UK EPR design increases degassing. This has the effect of transferring the maximum amount of carbon-14 into the gaseous effluent. EDF and AREVA claim this is BAT as the impact from gaseous disposal is less than that of aqueous disposal (0.008 µSv GBq^{-1} carbon-14 for gaseous is quoted against 0.15 for aqueous). We accept this claim. (EPRBs3.2)

140 The final element of the CVCS is a Volume Control Tank (VCT) with a nitrogen filled headspace. Dissolved gases, particularly noble gases, in the coolant will degas into the VCT headspace. The CVCS in the UK EPR is a closed system (similar to the KONVOI design). This is claimed as minimising the source of tritium to gaseous discharges from the Reactor Coolant System (PCERsc6.3s7.2.1). There is a purge from the VCT to the Gaseous Waste Processing System. The GWPS normally recycles the purge gas. This allows decay of shorter-lived noble gases before discharge. During plant start-up or shut-down a portion of the purge gas passes through driers to remove water vapour before entering three delay beds. The driers will act to reduce discharges of tritiated water to air. PCERsc8.2 Table 8 claims a reduction of 60% in gaseous tritium discharges compared to predecessor 1300 MWe plant. We accept that the UK EPR design uses BAT to minimise gaseous discharge of tritium from the RCS.

141 Any leakage from pipes or equipment containing reactor coolant could:

a) cause aerosols containing corrosion products, these would be collected by the ventilation systems and contribute to gaseous radioactive waste; and

b) contribute to liquid radioactive waste by way of the drain systems.

142 EDF and AREVA claim “reinforced leak-tightness requirements for active parts (pumps and valves) and the recovery of primary coolant leaks”. Recovery is demonstrated (PCERsc6.2s1.1.2.1) and PCERsc8.2s3.3.1 lists techniques used in the UK EPR to minimise leaks:

a) Bellows seals;

b) Reduced numbers of welds;

c) Double barriers made of a ring joint with a blocked port between the two rings;

d) Leak-off lines: pipes placed on valves to enable connection directly to drain system;

e) Double packing pressure seals.

We conclude BAT is used on the UK EPR to minimise leaks and thus minimise the potential for producing wastes.

143 There is a system to collect effluents produced in the UK EPR (PCERsc6.2s1.1.2.1). This is part of the Nuclear Island Vent and Drain system (NVDS). Effluents from the RCS are collected separately, unless potentially chemically polluted, and recycled into the Coolant Storage and Treatment System for treatment and reuse as coolant. We see this as BAT to minimise the volume of liquid waste requiring disposal.

144 The NVDS collects all other liquid effluents in a number of drains but maintains segregation to allow the most appropriate treatment before disposal, see PCERsc6.4s1 Figure 1, reproduced in the Annex of this report.

145 PCERsc6.4s2.1 Figure 2 (reproduced in the Annex of this report) shows the principle of routing of effluents. Choices can be made at effluent collection sumps as to route, with uncontaminated effluent sent directly to a discharge tank or contaminated effluent to an appropriate tank at the front end of the Liquid Waste Processing System. Again we see this as BAT as it allows the most effective treatments to be applied to minimise activity on disposal.

3.8.2 Secondary circuit

146 The secondary circuit contains boiler quality water that is made into steam in the Steam Generators (SGs). The steam drives turbines that generate electricity. The steam is condensed after the turbines and the condensate water reused. In the event of any tube leaks in the SGs the secondary circuit water could be contaminated with radioactivity, in particular tritium. There is a blowdown (bleed) from the secondary circuit used to control the solids content of the water. This is normally passed through a filter and demineraliser and recycled. If the blowdown cannot be recycled it is sent to a discharge tank for monitoring before disposal without further treatment. SG construction has been improved to minimise potential for leaks. There is no additional generation of tritium by this route. We accept the improvements to the SG construction as BAT to minimise the potential for a radioactive discharge by this route. (PCERsc6.2s1.1.2.3)

3.8.3 Ventilation systems

147 We require BAT to be used in the design of ventilation systems. Systems should include appropriate treatment systems to remove and collect airborne radioactive substances prior to their discharge to the air. (Our REPS (Environment Agency 2010b) ENDP16)

148 All radiation controlled areas within the UK EPR are served by ventilation systems (PCERsc6.2s1.2.3.2 Figure 10 – reproduced in the Annex of this report). This is considered to be ALARP to minimise radiation exposure to the workforce. Radioactive materials can occur in the ventilation air from trace leakage from active systems, EDF and AREVA claim “reinforced leak-tightness requirements”(PCERsc8.2s3.3.1), see paragraph 141 above.

149 The UK EPR design has minimised the potential for radioactivity to enter ventilation systems or the air by:

a) removing air operated valves from the reactor building, RB. This means there is no excess air entering the RB and no need to vent this during the power cycle. This removes a possible source of gaseous radioactive waste.

b) installing a metal skin inside the reactor building to prevent leakage of radioactive gases.

150 The main source of tritium for gaseous disposal is tritiated water evaporating from the surface of fuel pools and entering the ventilation systems. Disposal is to the main stack.

3.9 Containment of radioactive liquids in the UK EPR

151 Radioactive liquids will be produced in the UK EPR, we expect these liquids to be contained within the facility to prevent contamination of land or groundwater under normal conditions. Under fault conditions we expect a design to use BAT to minimise the probability of contamination occurring and the extent of contamination. (Our REPS (Environment Agency 2010b) RSMDP10 and CLDP1)

152 Under the Environmental Permitting Regulations 2010 (EPR 10), a permit is required for the deliberate discharge of certain substances, including radioactive substances, to groundwater, with the aim of avoiding pollution of groundwater.

153 EDF and AREVA claim that there is no likelihood of direct or indirect discharges of radioactive substances to groundwater. In that case a UK EPR should not need to be permitted by us for a discharge to groundwater under EPR 10.

154 EDF and AREVA claim that the UK EPR has several levels of techniques to contain liquids within the nuclear island and prevent contamination of groundwater (PCER sc8.3s3):

a) primary containment:
   i) metallic components are designed, manufactured and erected to ensure they remain leak-tight over the lifetime of the facility (see PCSRsc3.2s1 and Table 3, PCERsc8.2s3.3.1);
   ii) concrete pools, tanks and sumps that will hold liquids will be fitted with a metallic liner.
b) secondary containment: any leaks that do occur will be contained inside buildings or piping galleries:
   i) buildings are erected on a concrete raft with floor and part of walls coated to contain spills;
   ii) pipes that run outside buildings will be in leak-tight concrete galleries that can be inspected.
c) valves are installed on liquid circuits to allow isolation of any section with a leak;
d) leak collection systems operate in the nuclear island and the turbine hall. The sumps of these systems are fitted with systems to warn the operator, through the main Control and Instrumentation (C&I) system, of massive liquid inlet. An alarm is also given in event of excessive sump pump run time which could indicate a continuous smaller leak.
e) drains that pass through the base concrete are of a double wall construction, the inner pipe carrying effluent is within a larger outer pipe. When drain pipes enter sumps a special receptacle is placed to collect any leakage in the outer pipe and give a visual indication of a leak in the inner pipe.
f) sumps are fitted with visual inspection tubes so that any leakage from the liner into the concrete pit can be seen.
g) monitoring throughout the life of the plant:
   i) inspection of equipment during maintenance;
   ii) monitoring of groundwater.

155 EDF and AREVA state that concrete pools, in particular the spent fuel pool, and tanks in the nuclear island are fitted with a system to detect, locate and drain leaks from the liner of the concrete tanks.

156 EDF and AREVA claim that concrete tanks in the nuclear island are oversized to reduce the risk of overflow.

157 Effluents are collected at the front end of the Liquid Waste Processing System (LWPS) by tanks. EDF and AREVA claim that these together with the discharge tanks are sized to offer substantial hold up capacity to cover all reactor operating scenarios and represent BAT for storage of effluents on the UK EPR. (PCERsc8.2s3.3.4 and PCERsc6.4s1.1)

a) Floor drain storage – 2 x 75 m^3 steel tanks;

b) Process drain storage – 2 x 100 m^3 steel tanks;

c) Chemical drain storage – 2 x 160 m^3 steel tanks;

d) Distillates storage – 2 x 100 m^3 steel tanks.

158 EDF and AREVA provided us a document that provides design information for these tanks. The tanks are:

a) of stainless steel to design standard EN 14015;

b) have high level alarms;

c) are within a concrete bund of 440 m^3 available volume (our requirement is greater than 110% volume of largest tank, that is greater than 176 m^3).

We conclude that the UK EPR design, in terms of LWPS front end tank design and bunding, uses BAT.

159 EDF and AREVA state that the tank volumes were determined using operational feedback data from predecessor plants. They predict total volume of effluent for the UK EPR as 12,000 $m^3 y^{-1}$. The tanks are operated in pairs with one filling while the contents of the other are processed through the LWPS. EDF and AREVA claim that the emptying period is designed to be shorter than the filling period giving allowance for operational fluctuations in effluent produced, therefore contingency capacity as such is not required. There is the possibility to transfer effluent to the reserve ExLWDS tanks (see next paragraph) in the event of any problems. The length of fill periods will be variable depending on operational factors, EDF and AREVA are still engaged in studies to define UK EPR fill period ranges.

160 The UK EPR will have a set of discharge tanks outside the nuclear island:

i) LRMDS tanks – collecting effluent from the LWPS with peak maximum radioactivity concentrations (based on predecessor plant experience) of 7 MBq l^{-1} mostly tritium. This does not represent discharge concentrations, effluent at such concentrations would be recycled through the LWPS until acceptable for discharge.

b) ExLWDS tanks – reserve in case of LWPS or outfall problems, normally empty;

c) CILWDS tanks – collecting effluent from radiologically uncontrolled areas, usually uncontaminated. Tritium contamination is possible in event of leaks from the primary to secondary systems with an expected maximum level of 1.9 MBq l^{-1}.

161 EDF and AREVA say that discharge tank design will need to take account of site specific factors. They provide information from the Flamanville site (comprising 2 existing 1300MWe reactors, one EPR in construction and another possible EPR in the future) where tanks will be:

a) 6 LRMDS tanks, 3 ExLWDS tanks and 4 CILWDS tanks, each of 750 m^3 capacity (the number of tanks will be a site specific matter);

b) of concrete construction with a leak tight, reinforced liner;

c) fitted with high level alarms;

d) fitted with overflow pipes to the other discharge tanks.

162 We require the tank design to be BAT to contain the low activity level liquid effluents. We would not require additional containment such as bunding but will require details of

construction techniques and liner specification at site specific permitting. We would inspect tanks during construction and would expect to see the Operator implement a test and maintenance programme to ensure the tanks remain leak tight.

163 EDF and AREVA will recommend that Operators implement procedures for inspection of equipment through the life of a UK EPR to ensure it remains leak tight. These should include:

a) condition of pipework (lagging to be removed where necessary);
b) mechanical damage;
c) operation and integrity of pipe supports;
d) indication of leaks;
e) defects in threaded connections, measuring devices and impulse lines;
f) vibration, excessive noise.

164 EDF and AREVA will recommend that Operators of a UK EPR should establish a network of boreholes for sampling groundwater during construction. The network should remain in place during operation and be used to monitor groundwater quality and detect any contaminants that inadvertently reach the water table. We commend this as good practice for reassurance, we recommend that Operators contact us at the early stages of site specific designs so that we can advise on the appropriate location and construction of boreholes. Operators should also develop a conceptual site model for each specific site to aid location of boreholes.

165 We conclude at this stage that the UK EPR uses BAT to contain liquids and prevent contamination of groundwater in normal operation. The techniques employed should also minimise contamination under fault conditions. However the design of the discharge tanks needs to be resolved at the site specific stage, with an associated demonstration of BAT for size (sufficient capacity to cover all reactor operating scenarios) and leak-tight construction.

4 Public comments

166 We received no relevant public comments on this topic before the end of 2009. Any comments received after that time will be addressed in our final decision to be published in June 2011.

5 Conclusion

167 We conclude that overall the UK EPR uses the best available techniques to prevent the unnecessary creation of radioactive waste and, where wastes are created, minimises the generation of those wastes.

168 However our conclusion is subject to four other issues, which will need to be addressed site specific permitting.

169 Other issues:

a) Zinc injection as an option for the UK EPR to aid corrosion control.

b) Assessment of the removal of secondary neutron sources (to further minimise creation of tritium) when EPR operational information becomes available.

c) Review of the BAT assessment on the minimisation of the production of activated corrosion products for the following matters where possible improvements were identified in the PCER:

   i) corrosion resistance of steam generator tubes;

   ii) electro-polishing of steam generator channel heads;

   iii) specification of lower cobalt content reactor system construction materials;

   iv) further reducing use of stellites in reactor components, in particular the coolant pump;

   and incorporation of the improvements into the design where appropriate.

d) Provision of the design of the discharge tanks (LRMDS, ExLWDS and CILWDS tanks) with associated demonstration of BAT for size and leak-tight construction.

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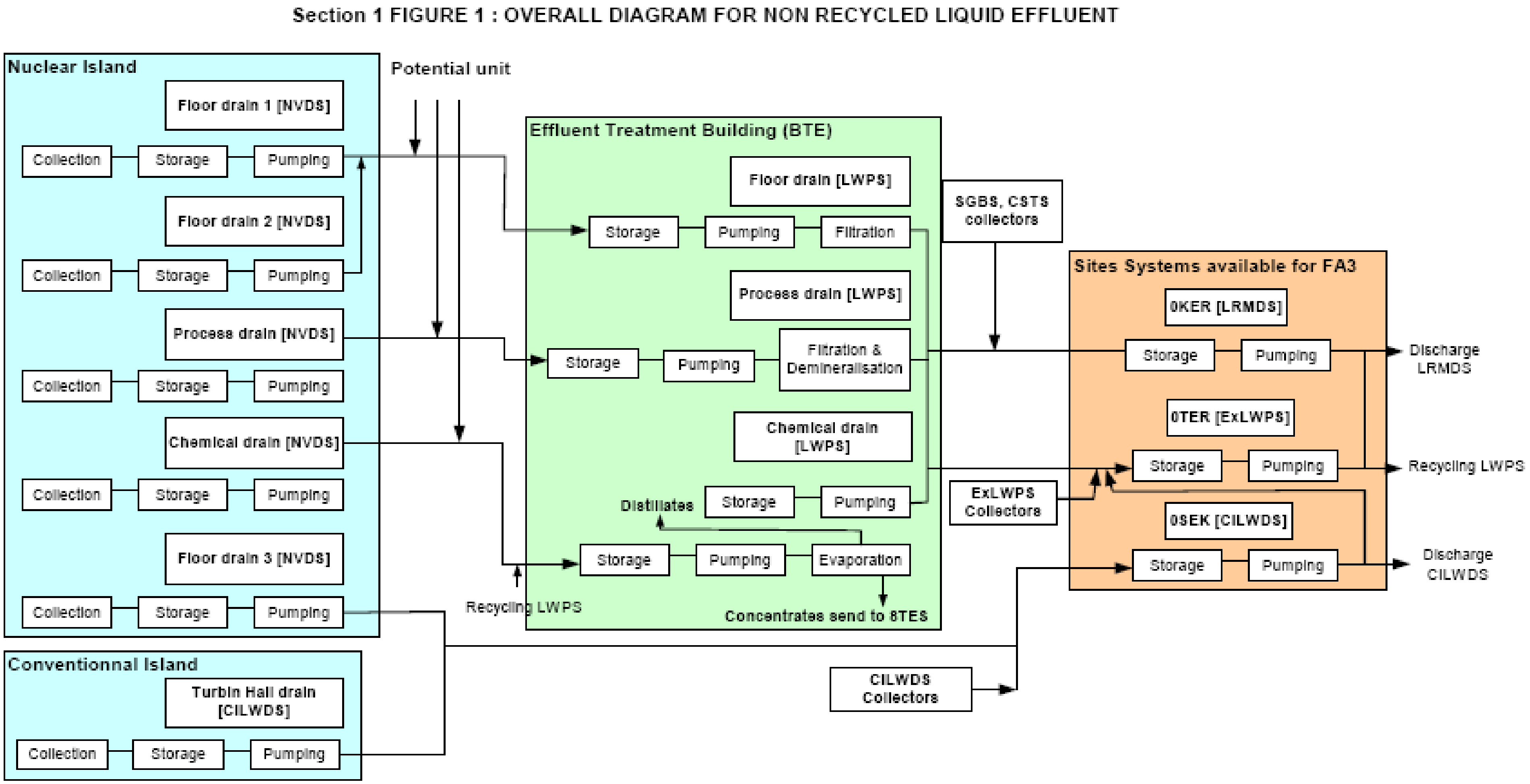
Abbreviations

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
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)
EPRI	Electric Power Research Institute
ETB	Effluent Treatment Building
ExLWDS	Additional liquid waste discharge system
FAPs	Fission and Activation Products
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
PCER	Pre-Construction Environmental Report
PCERsc3.3s4.1	PCER sub-chapter 3.3 section 4.1 (example reference)
PCSR	Pre-Construction Safety Report
PWR	Pressurised water reactor
RBWMS	Reactor Boron and Water Make-up System
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

Annex 1 Figures from PCER

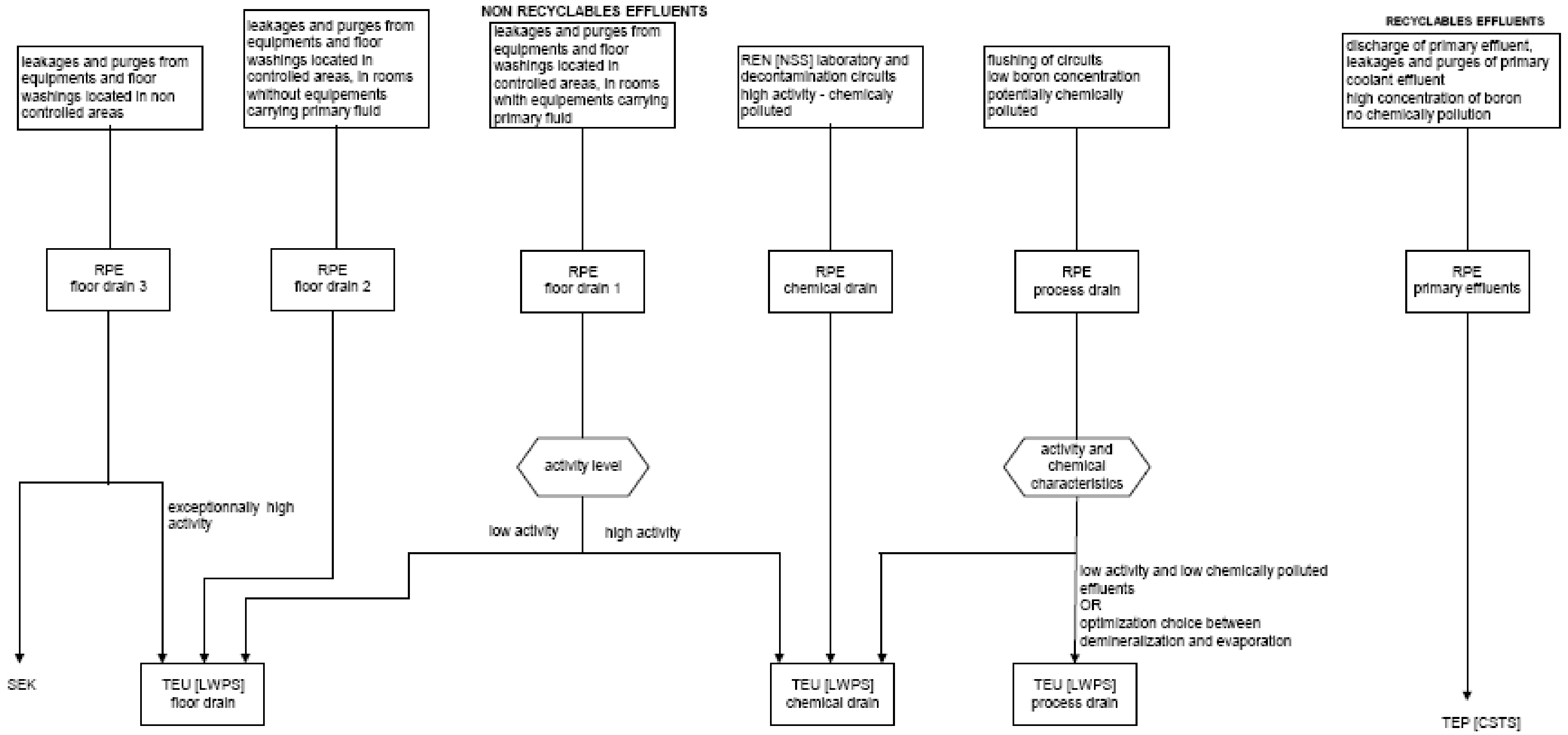
PCERsc6.4s1 Figure 1:



PCERsc6.4s2.1 Figure 2:

Section 2.1 FIGURE 2: RULES FOR CHANNELING EFFLUENT IN THE RPE [NVDS]

PRINCIPLE OF ROUTING OF EFFLUENTS IN RPE [NVDS] SYSTEM



PCERsc6.2s1.2.3.2 Figure 10

1.2.3.2. Treatment of gaseous effluent from ventilation

The following diagram summarizes the treatment of gaseous effluent from ventilation:

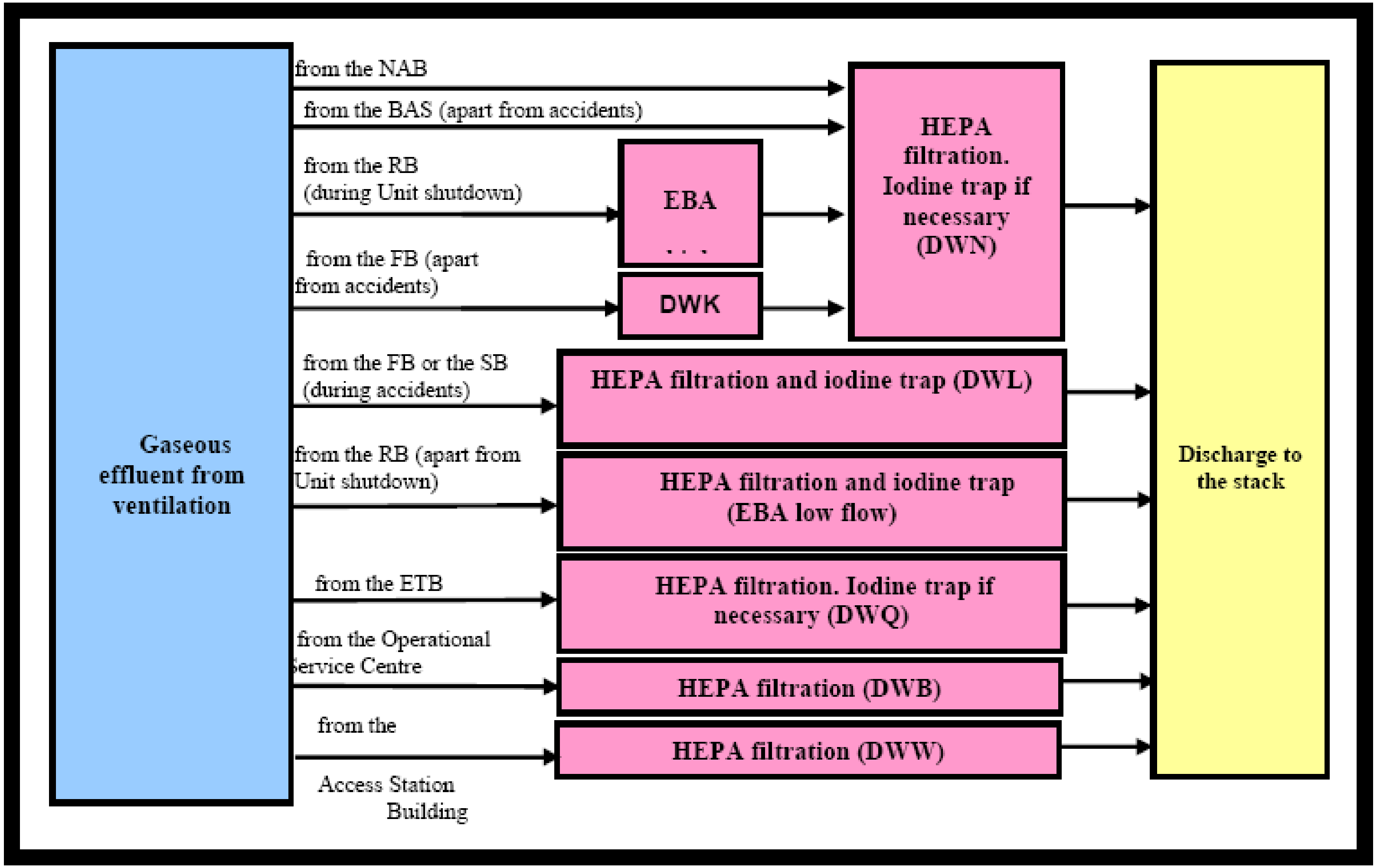


Figure 10: Treatment of gaseous effluent from ventilation

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