Generic design assessment

AP1000 nuclear power plant design by Westinghouse Electric Company LLC

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

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Assessment report – 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: 1.2 General information relating to the facility 1.5 An analysis should be provided that includes an evaluation of options considered and shows that the Best Available Techniques will be used to minimise the production and discharge or disposal of waste. 2.1 A description of how radioactive wastes will arise, be managed and disposed of throughout the facility's lifecycle.
Radioactive Substances Regulation Environmental Principles[2]	The following principles are relevant to this assessment: Principle RSMDP3 – Use of BAT to minimise waste: Principle RSMDP4 – Processes for Identifying BAT:. Principle RSMDP7 – BAT to Minimise Environmental Risk and Impact: Principle RSMDP8 – Segregation of Wastes: Principle RSMDP9 – Characterisation.
Report author	Julie Tooley

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 the creation of radioactive waste by the AP1000 based on information submitted by Westinghouse in its Environment Report and supporting documents.

2 We concluded that overall the AP1000 uses the best available techniques to prevent and minimise the creation of gaseous and aqueous radioactive waste and, where wastes are produced, minimises the generation of those wastes.

3 However our conclusion is subject to two other issues which will need to be addressed during site specific permitting**:**

a) The capability to include boron recycle in the AP1000 design shall be kept under review and a BAT assessment provided at site specific permitting to demonstrate whether boron recycling represents BAT.

b) Detailed arrangements for the hand over between Westinghouse and future operators shall be provided at site specific permitting, in particular with respect to matters that relate to the use of BAT to minimise radioactive discharges.

4 Our findings on the wider environmental impacts and waste management arrangements for the AP1000 reactor may be found in our Consultation Document (Environment Agency, 2010a).

2 Introduction

5 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.

6 This assessment considers the design of AP1000 with respect to the creation of radioactive material which may become waste, the foreseeable levels of radioactivity in radioactive waste and techniques that have been included in the design to minimise the creation of radioactive waste. The assessment considers the information provided by Westinghouse Electric Company LLC (Westinghouse, WEC) for its AP1000 design and the assessment aims to establish whether the design fulfils the requirements of UK Statute, policy and guidance on radioactive waste. The assessment also identifies key issues that should be taken forward into any discharge permit that may be issued in the form of relevant limitations and conditions along with any areas where insufficient information has been provided in GDA which results in a potential issue being set out at this stage of our considerations.

7 This assessment does not cover radioactive waste arising from decommissioning at the end of the reactor lifecycle.

8 The assessment aims to establish whether the design fulfils the requirements of UK Statute, policy and guidance on radioactive waste as currently written but it is recognised that the assessment should be kept under review to reflect changes in statute, policy and guidance that may occur between now and plant commissioning.

3 Assessment

9 This assessment considers the sources of radioactive materials in the AP 1000 that will eventually become waste and the techniques employed to minimise their creation. We expect new nuclear power plants to be designed to use 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. (Statutory Guidance (DECC, 2009) and our REPS (Environment Agency 2010b, see, RSMDP3))

10 The assessment has also considered the AP1000 design in the light of UK Statute, policy and guidance.

11 The key legislative areas that have been taken into account are:

a) Radioactive Substances Act 1993 (RSA93[1]) which is aimed at the control of radioactive substances (including waste).

b) Statutory guidance to the Environment Agency concerning the Regulation of Radioactive Discharges into the Environment (DECC, 2009) which sets out the principles that:

   i) regulatory justification of practices by the Government;

   ii) optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (the ALARA principle);

   iii) application of limits and conditions to control discharges from justified activities;

   iv) sustainable development;

   v) the use of Best Available Techniques (BAT);

   vi) the precautionary principle;

   vii) the polluter pays principle;

   viii) the preferred use of ‘concentrate and contain’ in the management of radioactive waste over ‘dilute and disperse’ in cases where there would be a definite benefit in reducing environmental pollution, provided that BAT is being applied and worker dose is taken into account.

c) Cm 2919 Review of radioactive waste management policy which sets out the principles that:

   i) radioactive waste is not created for which there are no current or foreseeable techniques for management;

   ii) that radioactive waste is not unnecessarily created,

   iii) that such wastes as are created are safely and appropriately managed and treated; and

   iv) that those wastes are safely disposed of at appropriate times and in appropriate ways.

12 Bearing in mind the legislative framework and the REPs, this assessment aims to establish the acceptability of the AP1000 design with respect to creation of radioactive waste.

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[1] As incorporated into the Environmental Permitting Regulations 2010.

3.1 Assessment Methodology

13 The basis of our assessment was to:

a) Consider the submission made by Westinghouse in particular the Environment Report and its supporting documents;

b) hold technical meetings with Westinghouse 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 Westinghouse insufficient;

d) assess the techniques proposed by Westinghouse 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 issues to carry forward from GDA in our Statement of Design Acceptability.

14 Westinghouse provided its submission to GDA in August 2007. We carried out our initial assessment and concluded we needed additional information. We raised a Regulatory Issue on Westinghouse 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”.

15 Westinghouse completely revised its submission during 2008 and provided an updated Environment Report with supporting documents.

16 We assessed information contained in the Environment Report but found that while much improved from the original submission it still lacked the detail we require to demonstrate BAT is used. We raised a Regulatory Observation (RO), RO-AP1000-034 on Westinghouse in June 2009 that had actions to provide:

a) a comprehensive Integrated Waste Strategy;

b) a demonstration that BAT will be used to prevent or minimise the creation and disposal of wastes

c) a demonstration that a Radioactive Waste Management Case can be developed to show the long term safety and environmental performance of the management of higher activity waste from their generation to their conditioning into the form in which they will be suitable for storage and eventual disposal.

17 We raised 42 Technical Queries (TQs) on Westinghouse during our assessment. One was relevant to this report.

a) TQ-AP1000-145 – Reactor coolant – zinc injection. 1 June 2009.

18 Westinghouse responded to all the ROs and TQs. They reviewed and updated the Environment Report in March-April 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 Environment Report (UKP-GW-GL-790 (Rev 3)) and its supporting documents in particular the AP1000 BAT Assessment (UKP-GW-GL-026 (Rev 1)).

3.2 Assessment Objectives

19 Key areas of the submission made under the GDA arrangements by Westinghouse for the AP1000 design that have been considered are:

a) Are all the sources of aqueous and gaseous radioactive waste 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 as superseded by Defra, 2010 and Environment Agency 2010c).

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

d) Do the options chosen for the AP1000 use Best Available Techniques to minimise the creation of radioactive waste?

20 The origins of radioactive materials within the UK AP1000 are primarily (ERs3):

a) fission products created in the fuel that may pass through the fuel cladding by diffusion or through leaks and enter the coolant;

b) dissolved or suspended corrosion products or other non-radioactive materials in the coolant that can be activated by neutrons as the coolant passes through the reactor core.

21 Westinghouse has provided information in its AP1000 BAT Assessment on the amount of certain radionuclides they would expect to generate during AP1000 operations for the following radionuclides or groups of radionuclides:

a) Tritium

b) Carbon-14

c) Nitrogen-16

d) Strontium-90

e) Iodine-131

f) Caesium-137

g) Plutonium -241

h) Noble gases

i) Other beta emitting particulate radionuclides which are produced by the activation of non-radioactive material. This group includes cobalt-58, cobalt-60, iron-55 and nickel-63.

22 We consider that, in line with our Considerations Document (Environment Agency, 2009 as superseded by Defra, 2010 and Environment Agency 2010c), Westinghouse has identified those radionuclides which either:

a) Contribute significantly to the amount of activity (Bq) in waste disposals;

b) Contribute significantly to potential dose to members of the public;

c) Indicate plant performance, for example where the levels of a radionuclide might increase in the event of a deviation from normal plant operation.

23 For each radionuclide Westinghouse have considered the options for preventing or minimising their creation at source and have scored the options against the following attributes:

a) Proven technology

b) Available technology

c) Effective technology

d) Ease of use

e) Cost

f) Impact in terms of doses to the public

g) Impact in terms of operator dose

h) Environmental impact

i) The ability to generate suitable waste forms

j) Secondary and decommissioning waste

3.3

3.4 Westinghouse documentation

24 We referred to the following documents to produce this report:

Document reference	Title	Version number
UKP-GW-GL-790	UK AP1000 Environment Report	3
UKP-GW-GL-026	AP1000 Nuclear Power Plant BAT Assessment	1
UKP-GW-GL-028	Proposed Annual Limits for Radioactive Discharge	1
EPS-GW-GL-700	AP1000 European Design Control Document	0
APP-WLS-M3C-049	Monthly Radiation Emissions from Radioactive Nuclides - AP1000 Calculation Note	2
APP-WLS-M3C-040	Expected Radioactive Effluents Associated with Advanced Plant Design - AP1000 Calculation Note	0

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

a) ER sub-chapter 6.2 section 1.2.1 = ERsc6.2s1.2.1;

4 BAT optioneering

26 The outcomes of the BAT optioneering exercise are summarised below:

4.1 Tritium

27 Tritium is a radioactive isotope of hydrogen. Westinghouse claim that tritium arises mainly from (BAT Assessment form 1):

a) unavoidable ternary fission of the uranium fuel. In ternary fission the uranium nucleus splits into 3 fragments which occurs in around 1 in 400 cases and one such fragment may be tritium which is able to diffuse through the fuel clad and into the coolant in the absence of fuel defects. The tritium formed is initially contained within the fuel cladding but may diffuse into the coolant. The rate of tritium released into the coolant is dependent on reactor power. Westinghouse claim that the zirconium fuel cladding (ZIRLO) used in the AP1000 is more effective at reducing diffusion than other cladding materials. Westinghouse use a 10% in-core tritium release to the coolant as the design basis which results in the production of 63 TBq of tritium per 18 month cycle. Westinghouse use a 2% release of tritium to the coolant as the best estimate of tritium production which results in the production of 13 TBq of tritium per 18 month cycle.

b) activation of the boron which is used as a burnable absorber either in discrete burnable absorber rods or as integral fuel burnable rods. The tritium will be produced within the cladding and may diffuse into the coolant. Westinghouse predict the production of tritium by this route to be 10 TBq per 18 month cycle (design basis) or 2 TBq per 18 month cycle(best estimate).

c) activation of boron-10 which is present as boric acid in the coolant. Boron is used to control the reactivity of the reactor. Westinghouse claim the use of two techniques for minimising production of tritium in the AP1000:

    i) the use of grey rod clusters for load following minimises the amount of coolant boron needed for reactor control and the need for changes to boron concentration (ERs3.2.8);

    ii) the use of burnable poisons (a boride coating or incorporation of gadolinium oxide within some fuel pellets) reduces the amount of boron required.

    iii) Westinghouse recognise that it is possible to use boric acid with an enriched boron-10 content to reduce the quantity of boron needed for reactor control but they claim this has no effect on the quantity of tritium produced. Westinghouse predict tritium production by this route to be 27 TBq per 18 month cycle.

d) activation of lithium-6 and lithium-7 present in the lithium hydroxide which is used for chemistry control of the coolant to offset the corrosive effect of boric acid. Westinghouse claim that the use of lithium hydroxide enriched to 99.9% of lithium-7 in the AP1000 minimises production of tritium (lithium-6 produces greater quantities of tritium than lithium-7). Westinghouse predict tritium production by this route to be 6 TBq per 18 month cycle.

e) activation of deuterium in the reactor coolant (deuterium is an isotope of hydrogen which is naturally present in water at 0.015%). We accept that the production of tritium from deuterium is unavoidable and there are no available techniques to minimise its production Westinghouse predict tritium production by this route to be 0.148 TBq per 18 month cycle.

28 Westinghouse have provided information on the predicted source terms for tritium used as a design basis where it is assumed that 10% of the in-core tritium is released to the coolant and best estimates of realistic source terms where it is assumed that 2% of the in-core tritium is released to the coolant.

Source of tritium	Design basis release to coolant (TBq per 18 month cycle)	Best estimate release to coolant (TBq per 18 month cycle)
Ternary fission in core	62.9	13.098
Burnable absorbers	10.323	2.072
Soluble boron in coolant	27.158	27.158
Soluble lithium in coolant	6.216	6.216
Deuterium in coolant	0.148	0.148
Total	**109.335**	**48.692**

29 Tritium is also produced by activation of boron-10, hydrogen-2, lithium-6 and lithium-7:

a) B-10 + n → 2(He-4) + H-3

b) D-2 + n → H-3

c) Li-6 + n_{th} → H-3 + He

d) Li-7 + n → He-4 + H-3 + n

30 Westinghouse estimate the source terms for tritium to be 37,0000 Bq g^{-1} in reactor coolant and 37 Bq g^{-1} in steam generator steam.

31 Westinghouse have identified the following options for the prevention or minimisation of tritium in the AP 1000 design:

a) Use of Lithium-7 hydroxide - The use of lithium-7 hydroxide for pH control rather than lithium-6 reduces the production of tritium since the neutron absorption cross-section of lithium-7 is five orders of magnitude smaller than that of lithium-6.

b) Zirconium cladding - The use of zirconium cladding for fuel can reduce the diffusion of tritium produced in the fuel through the cladding tube wall and thus into the primary coolant.

c) Use of enriched boron - the use of enriched boron (B-10) can reduce the total amount of boron required for chemical shim purposes.

d) Use of gray rods – Gray rods are moveable control rids with which contain a low density neutron absorber to provide reactivity control. The use of grey rods to aid load following can significantly reduce the amount of coolant borne boron needed for reactivity control and subsequent changes in boron concentration.

e) Boron recycling - Boron recycle systems can reduce the amount of boron used and hence the amount tritium discharged to the environment.

32 Westinghouse have scored the options and the use of zirconium cladding and grey rods scored highest, with the use if lithium-7 hydroxide scoring one point lower. The use of enriched boron scored five points lower than the top scoring options with boron recycling scoring lowest. Westinghouse claim that the use of lithium-7 hydroxide, grey rods and zirconium cladding are included in the AP 1000 design.

33 The key issues relating to tritium production are:

a) **Enriched boron in place of natural boron**. Westinghouse claim that natural boron is used to control reactivity in the reactor:

   i) Natural boron is 20% boron-10 and 80% boron-11.

   ii) Enriched boron-10 is a better neutron absorber than natural boron and is therefore a better chemical shim.

iii) The amount of tritium produced by natural boron and enriched boron-10 is similar using the amount of boron-10 as the basis (when using natural boron the concentration of boron will be higher to provide the same amount of boron-10).

iv) Grey rods are used as a mechanical means of controlling reactivity and reduce the amount of boron needed.

v) Burnable poisons e.g. gadolinium are used in the initial cycle to control reactivity and reduce the amount of boron needed.

As a result Westinghouse claim that the use of natural boron along with grey rods and burnable poisons provides a similar benefit in reducing tritium as the use of enriched boron along with grey rods and burnable poisons.

b) **Use of lithium-7 in place of lithium-6**. The AP1000 uses lithium hydroxide enriched in lithium-7 to 99.9 %. Lithium-7 has a smaller neutron absorbing cross section [five orders of magnitude] than lithium-6 and therefore less tritium is produced from lithium-7 than from lithium-6.

c) **Boron recycling**. Westinghouse has provided an options appraisal for techniques to minimise production of tritium in its AP1000 Nuclear Power Plant BAT Assessment. In its assessment Westinghouse has considered the use of boron recycle as a technique to minimise the production of tritium. Westinghouse claims that whilst boron recycle systems reduce tritium discharges to the environment there are disbenefits in terms of storage of coolant over a cycle, increased system complexity and an increase in plant and components for disposal at the decommissioning stage. These aspects conflict with the AP1000 design concept of simplicity. Additionally Westinghouse claims that the use of boron recycle could have an impact on operator dose.

34 We note that Westinghouse claims that boron recycling is not BAT for the UK AP1000 design submitted under GDA. The addition of boron recycling would involve significant design changes and add complexity to the reactor design but we understand that reactor operators favour boron recycling and this may be considered by Westinghouse in the future. We have considered the BAT argument relating to boron at the design reference point used in GDA which does not include boron recycling. We do recognise however that boron recycling would reduce the amount of primary coolant discharged to the environment and reduce the amount of tritium discharged therefore we expect Westinghouse to keep the feasibility of boron recycling in the AP1000 under review as part of its ongoing review of BAT. HSE would be involved in review of any proposal from Westinghouse to adopt Boron recycling since this could impact on its assessments of reactor chemistry and operator dose.

35 Westinghouse predicts the total production of tritium from an AP1000 to be 109.3 TBq per 18 month cycle (design basis) or 48.7 TBq per 18 month cycle (best estimate).

36 We consider that the techniques considered by WEC for minimising the production of tritium in the AP1000 are sufficiently comprehensive and represent feasible and proven techniques at this stage however we recognise that techniques may be developed in the future which may be worthy of consideration. We note that boron recycling is not included in the AP1000 design.

37 Whilst we recognise that alternative techniques such as the use of grey rods and burnable poisons may be more cost effective technique than the use of enriched boron or boron recycling for minimising the production of tritium at source, we consider that further information is required to demonstrate that the use of natural boron (as opposed to enriched boron) is BAT with respect to tritium production. We consider that the feasibility of including boron recycling in the AP1000 should be kept under review by Westinghouse as part of its ongoing review of BAT.

38 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of tritium in the AP1000. However we will require Westinghouse to keep the feasibility of including boron recycle in the AP1000 design under review and provide a BAT assessment at the site specific permitting stage.

39 We will include the following other issue in our GDA findings:

40 The capability to include boron recycle in the AP1000 design shall be kept under review and a BAT assessment provided at site specific permitting to demonstrate whether boron recycling represents BAT.

4.2 Carbon-14

41 Carbon-14 is created by the following mechanisms (BAT Assessment form 2):

a) Neutron activation of oxygen-17 (O-17 (n, α) → C-14) which is a naturally occurring stable isotope of oxygen in the coolant. Westinghouse claim they minimise the production of carbon-14 by eliminating free oxygen in the coolant. Westinghouse predict the amount of carbon-14 produced from oxygen-17 to be 552 GBq y^{-1}.

b) Neutron activation of nitrogen-14 (N-14 (n,p) → C-14) dissolved in the coolant. The AP1000 uses lithium hydroxide to control coolant pH as opposed to hydrazine which contains nitrogen and is used in some other designs. Using lithium hydroxide instead of hydrazine reduces the amount of nitrogen in the coolant and the amount of carbon-14 produced by this mechanism. Westinghouse have considered the use of argon as the cover gas for the coolant water supply tanks to minimise the dissolution of nitrogen. This would make the systems more complex and costly and Westinghouse do not consider the use of argon cover gas to be BAT for the AP1000. Assuming 15 ppm of nitrogen in the coolant Westinghouse predict the production of carbon-14 from nitrogen-14 to be 110 GBq y^{-1}.

c) The neutron activation of nitrogen-14 (N-14 (n,p) → C-14) in fuel. Nitrogen-14 in the fuel is minimised during the fabrication process during which the fuel rods are pressurised with helium which expels nitrogen from the fuel.

d) Carbon-14 is produced by the neutron activation of oxygen-17 (O-17 (n, α) → C-14) and nitrogen-14 (N-14 (n,p) → C-14) in stainless steel structural materials, however Westinghouse claim that the carbon-14 produced by these routes will remain in these materials.

42 Westinghouse claim that airborne release of C-14 from PWRs is predominantly hydrocarbons (75 – 95%), mainly methane, with only a small fraction in the form of CO_2.

43 Based on a nitrogen concentration of 15ppm in the primary coolant Westinghouse estimate the total rate of production of carbon-14 in the AP1000 to be:

Source of carbon-14	Design basis estimate (GBq y^{-1})
From oxygen-17	552
From nitrogen-14	110
Total	662

44 Westinghouse have considered the following techniques to prevent or minimise the production of carbon-14 at source:

a) Oxygen scavenging - Oxygen control of the demineralised water can be achieved by catalytic oxygen reduction units which reduce oxygen levels and by the addition of an oxygen scavenger during plant start up from cold shutdown.

b) Control of nitrogen impurities in the fuel rods - fuel rods can be pre-pressurised with helium to minimize compressive clad stresses and prevent clad flattening under reactor coolant operating pressures. The use of helium pressurisation expels nitrogen from the fuel rod.

c) Use of argon in pace of nitrogen as cover gas.

d) pH control using lithium hydroxide - pH control of the primary coolant can be achieved by using lithium hydroxide instead of hydrazine (NH2-NH2) which prevents formation of C-14 from nitrogen.

e) Electro-deionisation – the use of secondary demineralization can increase the removal of dissolved carbon dioxide gas.

45 Westinghouse have scored each option against the attributes listed in the BAT form of the BAT report including attributes such as proven technology and impact (operator dose, public dose), and the equal highest scoring options are oxygen scavenging and pH control, closely followed by control of nitrogen impurities in the fuel and electro-deionisation. Westinghouse claim that all these four measures are included in the AP1000 design.

46 Assuming 15 ppm nitrogen in the coolant Westinghouse predict the total production of carbon-14 to be 662 GBq y^{-1}.

47 We consider that the techniques considered by WEC for minimising the production of carbon-14 in the AP1000 are sufficiently comprehensive and represent feasible techniques at this stage however we recognise that techniques may be developed in the future which may be worthy of consideration.

48 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of carbon-14 in the AP1000.

4.3 Nitrogen -16

49 Nitrigen-16 is formed by the activation of oxygen-16 in the primary coolant. There is no practicable way to reduce its formation. However, its short half-life of 7.13 seconds means that discharges to the environment will be insignificant. (BAT assessment form 3).

50 The production of nitrogen-16 is prevented or minimised by:

a) Hydrazine addition – hydrazine can be injected to control the oxygen concentration in the primary circuit.

b) Oxygen elimination – the injection of hydrogen at power can minimise radiolysis in the core.

51 Westinghouse has scored both options equally against the attributes selected for its assessment. Westinghouse claims that both these measures are included in the AP1000 design.

52 We consider that the minimisation of the production of nitrogen-16 at source is primarily a matter for the HSE as the short half life of nitrogen-16 results in the key impact being in terms of operator dose.

53 We do not consider nitrogen-16 further in our assessment.

4.4 Strontium-90

54 Strontium-90 is a fission product normally contained within the fuel cladding. If there are any fuel defects strontium-90 can enter into the primary coolant.

55 Westinghouse estimate the design basis activity of strontium-90 in reactor coolant to be 1.813 Bq g^{-1} based upon assuming 0.25% fuel defects. Westinghouse estimate the

realistic source term in the AP1000 to be 0.37 Bq g^{-1} in reactor coolant and 2.59E-07 Bq g^{-1} in steam generator steam. (BAT Assessment form 4)

56 Westinghouse have not carried out an optioneering assessment for the prevention or minimisation of strontium-90 at source but they do claim that minimisation of fuel defects is key to minimising strontium-90 production. (BAT assessment form 4)

57 We consider that the production of strontium-90 is unavoidable however we recognise that techniques to minimise fuel defects which are used to minimise the production of other radionuclides will also minimise the production of strontium-90.

58 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of strontium-90 in the AP1000.

4.5 Iodine radionuclides

59 Iodine radionuclides are formed in the fuel by fission and can be released into the coolant as a result of defects in the fuel. In addition fission of uranium found on fuel and other surfaces (tramp uranium) can undergo fission and iodine radionuclides can be released into the coolant.

60 Westinghouse predict that design basis iodine-131 activity in reactor coolant will be 7.10E-01 µCi g^{-1} (26.3 kBq g^{-1}). Westinghouse predict the realistic source terms for iodine-131 to be 0.04 µCi g^{-1} (1.48kBq g^{-1}) in coolant and 2.7e-08 µCi g^{-1} (<1Bq g^{-1}) in steam generator steam. (BAT Assessment form 5)

61 We accept there are no techniques to prevent the production of iodine radionuclides within the fuel pins.

62 The majority of iodine radionuclides produced will form compounds and remain in the liquid phase of effluents from the CVS. A small fraction will remain as elemental iodine and will be degassed in the CVS and passed to the WGS. Any leaks from the primary coolant system could also result in iodine radionuclides being found in the containment atmosphere.

63 Westinghouse conclude that that the following techniques are BAT to minimise iodine-131 (and other iodine radionuclides) production in the AP1000:

a) Minimisation of fuel defects in operation – reactor operating regimes are used which minimise the likelihood of damage to the fuel and leaking fuel pins are located during refuelling and removed.

b) Control of uranium contamination on external surfaces of fuel (tramp uranium) in fuel manufacture and fabrication.

64 Westinghouse have scored each option against the attributes listed in the BAT form of the BAT report including attributes such as proven technology and impact (operator dose, public dose), and the highest scoring option is the minimisation of fuel defects in operation followed by the control of uranium contamination on external surfaces of fuel (tramp uranium) in fuel manufacture and fabrication. Westinghouse claim that both these measures are included in the AP1000 design.

65 We consider that the techniques considered by Westinghouse for minimising the production of iodine-131 (and other iodine radionuclides) in the AP1000 are sufficiently comprehensive and represent feasible and proven techniques.

66 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of iodine-131 (and other iodine radionuclides) in the AP1000.

4.6 Caesium 134 and caesium-137

67 Caesium 134 and caesium-137are fission products normally contained within the fuel cladding. If there are any fuel defects caesium radionuclides can enter the primary coolant. Fission of uranium contamination in the reactor (tramp uranium) can also be a source of caesium-134 and caesium-137. Caesium is highly soluble and, if present in the coolant, will eventually be treated in the WLS. The detection of caesium radionuclides in liquid radioactive waste disposals provides a useful indication of fuel integrity.

68 Westinghouse conclude that the following techniques are BAT to minimise caesium-137 production in the AP1000 (BAT assessment form 6):

a) Minimisation of fuel defects in operation – reactor operating regimes are used which minimise the likelihood of damage to the fuel and leaking fuel pins are located during refuelling and removed.

b) Control of uranium contamination on external surfaces of fuel (tramp uranium) in fuel manufacture and fabrication.

69 We consider that the techniques considered by Westinghouse for minimising the production of caesium-137 in the AP1000 are sufficiently comprehensive and represent feasible and proven techniques and will also minimise the production of caesium-134.

70 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of caesium-137 in the AP1000.

4.7 Noble gases (argon-41, krypton-85m, krypton-85, xenon-133m and xenon-133)

71 Noble gas radionuclides such as krypton-85, krypton-85m, xenon-133 and xenon -133m are fission products and are produced by fission of the uranium in the fuel. They are normally contained within the fuel cladding. However if there are any fuel defects these gases can enter into the reactor coolant. (BAT assessment form 8).

72 Even though there may be no defective fuel pins, natural uranium contamination of core construction materials and the fuel cladding, as well as enriched uranium contamination of external cladding surfaces during manufacture can also be a source of fission products in the coolant during power operations. However, Westinghouse claim this is insignificant in modern fuel manufacturing Noble gas radionuclides dissolved in the coolant will be removed by degassing in the CVS and pass through the WGS and be discharged to the air.

73 Westinghouse claim that fuel leak rate in existing AP 1000 plants is much less than the AP 1000 design basis value of 0.25% which is used to estimate liquid and gaseous radioactive waste discharges and that current fuel design has been improved, both in terms of the integrity of fuel rods and the robustness of the fuel assembly with respect to vibration of the rods within the assembly (ER s3.2.4).

74 Westinghouse have provided information on the sources of noble gases (argon-41, krypton-85m, krypton-85, xenon-133m and xenon -133) in the AP1000.

75 Westinghouse predict the noble gases source terms in reactor coolant to be:

Radionuclide	Design basis source term activity in reactor coolant ($Bq\ g^{-1}$)	Realistic source term activity in reactor coolant ($Bq\ g^{-1}$)
Argon-41	not detectable	not detectable
Krypton-85m	31,080	7,770
Krypton-85	111,000	51,800
Xenon-133m	62,900	40,700
Xenon-133	4,440,000	3,441

76 Westinghouse have considered the one technique to prevent or minimise the production of noble gases at source:

a) Minimisation of fuel defects in operation – reactor operating regimes can be used which minimise the likelihood of damage to the fuel and leaking fuel pins can be located during refuelling and removed.

77 Westinghouse have scored the single option against the attributes listed in the BAT form of the BAT report including attributes such as proven technology and impact (operator dose, public dose), and claim that measures to minimise fuel defects are included in the AP1000 design.

78 Westinghouse conclude that that the minimisation of fuel defects in operation, the use of reactor operating regimes which minimise the likelihood of damage to the fuel, and the location and removal of leaking fuel pins during refuelling, is BAT to minimise noble gas production in the AP1000.

79 We recognise however that the use of reactor operating regimes which minimise the likelihood of damage to the fuel and the location and removal of leaking fuel pins during refuelling will be a matter for future operators of the AP1000 and we will continue to seek assurances that hand over between Westinghouse and future operators will address this matter. We will include the following other issue in our GDA findings:

a) Detailed arrangements for the hand over between Westinghouse and future operators shall be provided at site specific permitting, in particular with respect to matters that relate to the use of BAT to minimise radioactive discharges.

80 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of noble gases from the fuel in the AP1000.

81 Argon-41 is produced by the activation of natural argon-40 in air surrounding the reactor in the containment area. Westinghouse predict that 1,300 GBq y^{-1} of argon-41 will be produced in the AP1000. Argon-41 is collected by the ventilation system and discharged through the main vent without treatment.

82 We consider that, taking into account that the production of argon-41 is unavoidable, its short half life (109 minutes) and low radiological impact, it is not proportionate to assess BAT in detail for argon-41. Discharges of argon-41 will be monitored and measured with other noble gases at the main plant stack and the turbine building stack.

4.8 Beta emitting particulates

83 Westinghouse have provided information on the sources of beta emitting particulates activity (cobalt-58, cobalt-60, iron-55 and nickel-63) in the AP1000:

a) **Cobalt-58** is formed by the activation of nickel-58, a stable isotope of nickel, which is a major constituent of the AP1000 steam generator tubes and the stainless steel used to fabricate the core and the reactor pressure vessel components. Westinghouse claim they minimise the potential for the production of cobalt-58 by:

   i) specifying metals that resist the corrosive effect of the coolant thus reducing corrosion products available to be activated;

   ii) only using nickel-based alloys where component reliability may be compromised by the use of other materials, e.g. the steam generator tubes;

   iii) pre-passivation of the steam generator to develop a single, chromium-rich layer which reduces corrosion product release.

b) **Cobalt-60** is formed by the activation of cobalt-59 in the reactor steel. Cobalt is also found in the hard-wearing alloy, Stellite™ which may be used on hardfacing components. Westinghouse claim they have minimised the amount of cobalt-60 produced in the AP1000 by minimising the amount of cobalt bearing materials used in the design using the following techniques:

   i) using low or zero cobalt alloys for hardfacing materials in contact with coolant unless necessary for reliability considerations;

   ii) limiting cobalt content of components in contact with coolant;

   iii) specifying low cobalt content (0.015 %) tubing for the steam generator.

c) **Iron-55** is formed by the activation of the stable isotope iron-54 found the reactor steel. Minimisation of use is not practicable. Control of corrosion by the choice of appropriate materials and the general measures described below will minimise production of corrosion products that may be activated.

d) **Nickel-63** is formed by the activation of the stable isotope nickel-63 found in nickel alloys, in particular the steam generator tubes. Minimisation of the production of nickel-63 is achieved by the same techniques as for cobalt-60.

84 Westinghouse predict the beta emitting particulates source terms in reactor coolant to be:

Radionuclide	Design basis source activity ($Bq\ g^{-1}$)	Realistic source activity ($Bq\ g^{-1}$)
Cobalt-58	70.3	144.3
Cobalt-60	8.14	16.28
Iron-55	18.5	37
Nickel-63	No information provided	No information provided

85 The production of beta emitting particulates is generally by activation of stable isotopes in the materials of the reactor and subsequent release into the primary coolant by corrosion, wear or thermal shock.

86 Options for the prevention or minimisation of the production of beta emitting particulates include:

a) Materials selection and QA - control of the choice of materials in contact with the primary coolant can lead to a reduction in the production of corrosion products including Co-58, Co-60, Fe-55 and Ni-63. Quality assurance and quality control systems during manufacture and construction can contribute to low corrosion rates.

b) Maintenance of an elevated pH - a constant elevated pH value can be maintained in the primary coolant by optimised regulation of the lithium concentration. This chemical is chosen for its compatibility with the materials and water chemistry of borated water / stainless steel / nickel-chromium-iron systems.

c) Hydrazine addition - during plant startup from cold shutdown hydrazine can be introduced as an oxygen scavenging agent.

d) Oxygen elimination - during power operations, dissolved hydrogen can be added to the reactor coolant system to eliminate free oxygen produced by radiolysis in the core and to prevent ammonia formation. This can reduce the oxygen content and limits radiolysis.

e) Zinc injection into the primary system - injection of zinc causes:

   i) Corrosion films to become thinner but more stable, reducing ongoing corrosion of reactor vessel materials.

   ii) Divalent cations to be displaced, released into the coolant, and blocked from redeposition.

   iii) A reduction in the risk of a crud induced power shift (CIPS).

f) Piping design - the piping in pipe chases can be designed with consideration for corrosion and operating environment. Pipe bends can be used instead of elbows where practicable to reduce potential crud traps. Welds can be made smooth to prevent crud traps from forming.

87 Westinghouse have scored all the options against the attributes listed in the BAT form of the BAT report including attributes such as proven technology and impact (operator dose), and piping design scored the highest by only one point. All other options scored equally. Westinghouse claim that all these measures are included in the AP1000 design.

88 We raised a Technical Query (TQ-AP1000-145) on 1 June 2009 requiring Westinghouse to confirm if the zinc injection was carried out using depleted zinc. Zinc-64 is transformed into zinc-65 by neutron capture. Zinc-65 has a half-life of 244.26 days and emits gamma radiation with an energy of 2.27 MeV. Zinc-64 has a natural abundance of 48.6%, but in depleted zinc it is reduced below 1%. The use of depleted zinc therefore reduces corrosion which minimises aqueous liquid radioactive waste discharges whilst reducing occupational exposure compared to the use of natural zinc.

89 Westinghouse responded on 17 June 2009 confirming that depleted zinc will be used for the AP1000.

90 We consider that the techniques considered by Westinghouse for minimising the production of activated corrosion products in the AP1000 are sufficiently comprehensive and represent feasible techniques at this stage however we recognise that techniques may be developed in the future which may be worthy of consideration.

91 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of activation products in the AP1000.

92 Westinghouse claim that a fundamental design goal of AP1000 has been to limit source terms through implementation of such advances as improved fuel, improved operational chemistry, and overall simplification (which limits leakage pathways).

93 Westinghouse claim that fission gases will normally be retained within the reactor coolant, and all planned coolant releases will be routed to the liquid radioactive waste system where the gaseous component is stripped and routed to the gaseous radioactive waste system. Westinghouse claim that releases from the heating,

ventilation and air conditioning (HVAC) filters only arise as a result of incidental leakage from the reactor coolant system. They claim that a major design emphasis of AP1000 has been to minimise this incidental leakage, through such measures as:

a) Use of canned motor reactor coolant pumps, which are hermetically sealed.

b) Simplification of the loop configuration and connecting piping, which reduces the number of potential release pathways.

c) Implementation of a full-flow letdown degasifier, which eliminates the need to store gas-laden liquids in tanks within the WLS.

4.9 Radioactive actinides

94 Radioactive actinides are formed in the fuel and can enter the coolant as a result of fuel leaks. They are also formed in any trace surface contamination of the fuel pins by fuel (tramp uranium), although the amount of tramp uranium is insignificant (see ERs3.2.3). They may enter the coolant and may be significant in terms of the impact of disposals as the majority are alpha emitters.

95 No information has been provided on the amount of alpha emitting radioactive actinides expected to be produced by the AP1000 however ER Table 3.4-6 lists the following actinides as having a negligible annual discharge to the sea: uranium-234, uranium-235, uranium-238, neptunium-237, plutonium-238, plutonium -239, plutonium -240, plutonium -242, americium-241, americium-243, curium-242 and curium-244.

96 Information has been provided about plutonium -241 which is a beta emitting actinide. The amount of plutonium-241 expected to be produced has not been given, however information has been provided about the average amount of plutonium-241 in liquid discharges which is predicted to be 0.00008 GBq y^{-1}.

97 We accept that the production of Pu-241 is an inevitable consequence of uranium fission reactions and cannot be prevented in the fuel. Westinghouse claim that the following techniques used in the AP1000 are BAT to minimise the quantity of Pu-241 potentially present in the coolant:

a) improved cladding material and quality control in manufacture has greatly reduced the incidence of fuel pin failures (see also noble gases above);

b) control of uranium contamination in the manufacture of fuel pins;

c) minimising plant shutdowns;

d) ultrasonic fuel cleaning.

98 We consider that the techniques considered by Westinghouse for minimising the production of plutonium-241 in the AP1000 are sufficiently comprehensive and represent feasible and proven techniques.

99 We recognise however that minimising plant shutdowns will be a matter for future operators of the AP1000 and we will continue to seek assurances that hand over between Westinghouse and future operators will address this matter. We will include the following other issue in our GDA findings:

a) Detailed arrangements for the hand over between Westinghouse and future operators shall be provided at site specific permitting, in particular with respect to matters that relate to the use of BAT to minimise radioactive discharges.

100 We consider that Westinghouse has demonstrated that BAT is used to minimise the production of plutonium-241 in the AP1000.

5 Measures to minimise the amount of radioactivity at source

101 Informed by its BAT optioneering assessment, Westinghouse claims there are a number of measures in the design of the AP1000 which will prevent or minimise waste at source (ERs3.1) and with respect to minimising liquid radioactive waste these include:

5.1 Fuel Rod and Cladding Design

102 The AP1000 fuel rods consist of cylindrical, ceramic pellets of slightly enriched uranium dioxide (UO2). These pellets are contained in cold-worked and stress-relieved ZIRLO clad tubing, which is plugged and seal-welded at the ends to encapsulate the fuel. ZIRLO is an advanced zirconium-based alloy which has a high corrosion resistance to coolant, fuel, and fission products, and high strength and ductility at operating temperatures. Westinghouse claim that the selection of ZIRLO cladding materials minimises the formation of defects that can result in radioactive releases to the reactor coolant.

5.2 Materials Selection

103 To reduce activation of cobalt to Co-60 a qualified low or zero cobalt alloy equivalent to Stellite-6 is primarily used for hard-facing material in contact with reactor coolant. The use of cobalt base alloy is minimized. Low or zero cobalt alloys used for hard-facing or other applications where cobalt alloys have been previously used are qualified using wear and corrosion tests.

104 However based on significant engineering experience cobalt-based alloys are used to a limited extent in the control rod drive mechanisms.

105 Westinghouse claim that cobalt-based alloys have limited use in the AP 1000 design.

5.3 Minimization of Leakage Pathways

106 Westinghouse claim that the AP1000 is designed with fewer valves and components than predecessor plants which will result in fewer leakage pathways and lower overall input to the radioactive waste systems.

5.4 Control of Reactor Coolant Water Chemistry

107 The reactor coolant system (RCS) contains boric acid for long-term reactivity control of the core. The following chemicals are added to the borated coolant:

a) Lithium hydroxide (Li7OH) is used to control the pH of the reactor coolant system and is chosen for its compatibility with borated water chemistry and the stainless steel and zirconium materials. The use of Li7OH, where the Li-7 isotope has been enriched, as opposed to Li6OH also removes an important formation mechanism for tritium. Westinghouse claim that the effective control of pH reduces the formation of radioactive corrosion products that may be released in liquid effluent.

b) Hydrazine is introduced as an oxygen scavenger during plant startup from cold shutdown. Westinghouse claims that the removal of dissolved oxygen reduces corrosion product formation.

c) Dissolved hydrogen. Westinghouse claims this eliminates free oxygen produced by radiolysis in the core and prevents ammonia formation.

d) Zinc acetate is added from the start of operations to minimise corrosion. Westinghouse claims this reduces radioactive cobalt and activated nickel concentrations.

108 The RCS water chemistry is routinely analyzed to ensure that the chemistry is correct and that corrosion product particulates are below specified limits.

109 We raised a Technical Query (TQ-AP1000-145) on 1 June 2009 asking Westinghouse to provide further information on the use of zinc in water chemistry control. In its response Westinghouse confirmed that the standard AP1000 design includes continuous zinc injection during power operation which is aimed at reducing crud induced power shifts and to mitigate against stress corrosion cracking. We asked Westinghouse to confirm if the zinc acetate used would contain depleted zinc as this would result in less zinc-65 being formed in the primary circuit and hence less zinc-65 in any liquid discharges. Westinghouse confirmed that when operational the AP1000 will use depleted zinc primarily because this will have a beneficial effect on operational dose rates and reduce worker dose but also because it will minimise corrosion product transport in the coolant which will be beneficial in terms of the activity of corrosion products in liquid discharges. Westinghouse claim that other nuclear power plants in Europe use depleted zinc and that US utility experience is set out in the EPRI document Pressurised Water Reactor Zinc Application Guidelines (see TQ 145). We note HSE has raised some concern about reliance on Zn for fuel protection.

5.5 Grey Rods and Burnable Absorber Rods

110 Core reactivity is controlled by means of a chemical poison (boric acid) dissolved in the coolant, rod cluster control assemblies, grey rod cluster assemblies and burnable absorbers.

111 Grey rods are moveable control rids with which contain a low density neutron absorber to provide reactivity control. The grey rod cluster assemblies are used in load follow manoeuvring and provide a mechanical shim reactivity mechanism which eliminates the need for chemical shim control provided by changes to the concentration of soluble boron.

112 Discrete burnable absorber rods or integral fuel burnable absorber rods or both may be used to provide partial control of the excess reactivity available during the fuel cycle. In doing so, the burnable absorber rods reduce the requirement for soluble boron in the moderator at the beginning of the fuel cycle.

113 Westinghouse claim that the reactor controls provided by grey rods and burnable absorber rods reduces the requirement for varying the boron concentrations in the reactor coolant system and thus the volume of reactor coolant that is withdrawn by the CVS and treated in the liquid radioactive waste system is reduced.

5.6 Recycling Steam Generator Blow Down

114 Steam generator blowdown fluid is recycled and normally returned to the condensate system.

5.7 Improved fuel, operational chemistry and overall simplification

115 Gaseous releases with the greatest radiological consequence are fission gases originating within the fuel pellet, which could have a potential impact on the public if they leak out to the environment through the various barriers. Westinghouse claim that a fundamental design goal of AP1000 has been to limit source terms through implementation of such advances as improved fuel, improved operational chemistry, and overall simplification (which limits leakage pathways).

116 Westinghouse claim that fission gases will normally be retained within the reactor coolant, and all planned coolant releases will be routed to the liquid radioactive waste system where the gaseous component is stripped and routed to the gaseous radioactive waste system. Westinghouse claim that releases from the heating,

ventilation and air conditioning (HVAC) filters only arise as a result of incidental leakage from the reactor coolant system. They claim that a major design emphasis of AP1000 has been to minimise this incidental leakage, through such measures as:

a) Use of canned motor reactor coolant pumps, which are hermetically sealed.

b) Simplification of the loop configuration and connecting piping, which reduces the number of potential release pathways.

c) Implementation of a full-flow letdown degasifier, which eliminates the need to store gas-laden liquids in tanks within the WLS.

117 Our Radioactive Substances Environmental Principle RSMDP3 requires 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.

118 We consider that Westinghouse have considered a comprehensive range of techniques for the minimisation of liquid radioactive waste at source however we recognise that techniques may be developed in the future which may be worthy of consideration. We consider the overall outcome of the BAT optioneering relating to minimising the production of liquid radioactive waste at source to be reasonable and to fulfil the requirements of RSMDP3 at this stage.

6 Compliance with Environment Agency requirements

P&I Table 1 section or REP	Compliance comments
1.2 General information relating to the facility	Westinghouse provided general information relating to the facility.
1.5 An analysis should be provided that includes an evaluation of options considered and shows that the Best Available Techniques will be used to minimise the production and discharge or disposal of waste.	Westinghouse provided a BAT Assessment Report which considered BAT in relation to minimising the production of radioactive material and waste.
2.1 A description of how radioactive wastes will arise, be managed and disposed of throughout the facility's lifecycle.	Westinghouse provided a description of how radioactive wastes will arise.
Principle RSMDP3 – Use of BAT to minimise waste: The best available techniques should be used to ensure that production of radioactive waste is prevented and minimised where that is not practicable with regard to activity and quantity.	Westinghouse provided a BAT Assessment Report which considered BAT in relation to minimising the production of radioactive material and waste. We consider that BAT will be used to minimise the production of radioactive waste subject to the other issues referred to in our conclusions.
Principle RSMDP4 – Processes for Identifying BAT: The best available techniques should be identified by a process that is timely, transparent, inclusive, based on good quality data, and properly documented.	Westinghouse provided a BAT Assessment Report which considered BAT in relation to minimising the production of radioactive material and waste using a systematic process which identified, scored and ranked options.
Principle RSMDP7 – BAT to Minimise Environmental Risk and Impact: When making decisions about the management of radioactive substances, the best available techniques should be used to ensure that the resulting environmental risk and impact are minimised.	Westinghouse provided a BAT Assessment Report which considered BAT in relation to minimising the production of radioactive material and waste which included information on the impact.
RSMDP8 – Segregation of Wastes: The best available techniques should be used to prevent the mixing of radioactive substances with other materials, including other radioactive substances, where such mixing which might compromise subsequent effective management or increase environmental impacts or risks.	
RSMDP9 – Characterisation: Radioactive substances should be characterised using the best available techniques so as to facilitate their subsequent management, including waste disposal.	

7 Public comments

119 No public comments were received relating to the production of radioactive waste during this assessment.

8 Conclusion

120 We concluded that overall the AP1000 uses the best available techniques to prevent and minimise the production of gaseous and aqueous radioactive waste and, where wastes are produced, minimises the generation of those wastes.

121 However our conclusion is subject to two other issues which will need to be addressed during site specific permitting:

a) The capability to include boron recycle in the AP1000 design shall be kept under review and a BAT assessment provided at site specific permitting to demonstrate whether boron recycling represents BAT.

b) Detailed arrangements for the hand over between Westinghouse and future operators shall be provided at site specific permitting, in particular with respect to matters that relate to the use of BAT to minimise radioactive discharges.

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Abbreviations

ALARA	As low as reasonably achievable
ALARP	As Low As Reasonably Practicable
BAT	Best available techniques
CVS	Chemical and Volume control system
CWS	Circulating water system
DCD	Design Control Document
EPR 10	Environmental Permitting (England and Wales) Regulations 2010
EPRI	Electrical Power Research Institute – an independent USA organisation
ER	Environment Report
GDA	Generic design assessment
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
JPO	Joint Programme Office
P&ID	Process and information document
PCSR	Pre-Construction Safety Report
PWR	Pressurised water reactor
QA	Quality Assurance
RCS	Reactor coolant system
REPs	Radioactive substances environmental principles
RGN	Regulatory Guidance Note
RGS	Regulatory Guidance Series
RO	Regulatory Observation
SODA	Statement of Design Acceptability
TQ	Technical Query
US NRC	United States Nuclear Regulatory Commission
WEC	Westinghouse Electric Company LLC
WGS	Gaseous radioactive waste system
WLS	Liquid radioactive waste system

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