Sizewell C Project

Radioactive Substances Regulation (RSR) Permit Application

Appendix A

Support Document A1 – Environment Case

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1 Introduction

1.1 Purpose

1. The purpose of this Support Document is to describe the application of Best Available Techniques (BAT) (as defined in the Sizewell C (SZC) Radioactive Substances Regulation (RSR) permit application head document [Ref 1]) as part of the permit application to demonstrate how BAT has been implemented within the SZC design, and how NNB Generation Company (SZC) Ltd. (SZC Co.) will ensure compliance with permit conditions throughout the lifetime of the project.

2. It demonstrates that the practice of generating electricity from the UK EPR^{TM} at SZC is considered to be optimised at this stage of the project and that BAT are being applied. It is recognised that the demonstration of BAT is a continuous process, which will evolve and grow in parallel with the design, construction, operation and eventual decommissioning of the SZC nuclear power station.

3. SZC Co. has focussed on techniques that reduce the amount of radioactive waste that is created and disposed of to the environment. Where disposal is unavoidable further techniques are deployed to ensure that consequences of such disposals are As Low As Reasonably Achievable (ALARA). These techniques typically cover a range of engineering and management processes and practices and, when taken together, they are referred to as BAT.

4. The application of BAT is a pre-requisite for applying for limits for discharges of radioactive waste to the environment. The submission that SZC Co. is making for discharge limits, described in RSR Permit Application Support Document B [Ref 2], takes full account of the benefits that are derived from the application of BAT.

5. This document builds on the foundations presented in the Generic Design Assessment (GDA) for the UK EPR^{TM} and the Hinkley Point C (HPC) permit application [Ref 3] in 2011; as HPC is the sister site to SZC and share a common nuclear island design.

1.2 Scope

6. This document summarises the SZC Environment Case, which is the vehicle via which SZC Co. demonstrates the ongoing application of BAT throughout the lifecycle of the project, in line with Environment Agency guidance [Ref 4]. As part of the RSR Permit application submission, SZC Co. developed the Environment Case to demonstrate how the company implements BAT, in order to avoid or reduce waste/ emissions arising from the site and to reduce the impact on the environment as a whole. The SZC Environment Case, mirrors that which exists for the HPC project, which has been developed and maintained by NNB Generating Company (HPC) Ltd. (NNB GenCo (HPC)).

7. The Environment Case covers 4 main areas:

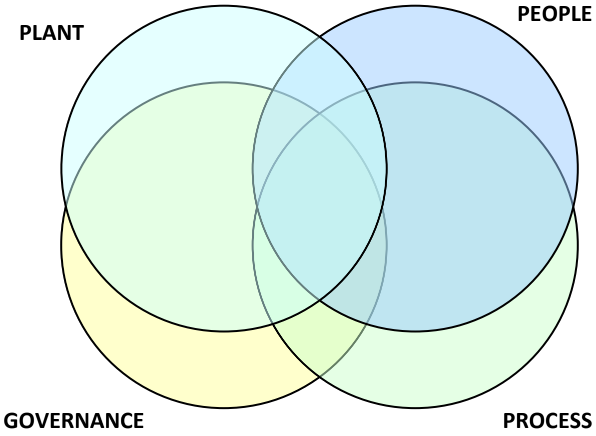

Figure 1-1 Structure of the Environment Case

- Plant – The physical resources and assets of SZC Co. This includes the systems, structures and components, and how these are optimised through design, manufacture, commissioning and operation.
- People – The human resource elements of SZC Co. including training, development and competency.
- Governance – The financial resources and corporate governance arrangements of SZC Co. This includes ensuring that the company has processes in place to manage Environmental Policy and Legislation.
- Process – This is the management and compliance arrangements of SZC Co. including company policies, procedures and guidelines.

8. This document is concerned with the demonstration that the ‘Plant’ aspect of the SZC project represents BAT. The ‘People’, ‘Process’ and ‘Governance’ aspects of the SZC Environment Case are out of scope of this document, and are covered within permit application head document [Ref 1] and the other supporting documents.

9. SZC shares a common design with the HPC Nuclear Island, and it is appropriate that with regards to the ‘Plant’ aspect, that the HPC Environment Case be used as a starting point for the Development of the Environment Case for SZC. This is consistent with the SZC replication strategy, set out in the SZC radioactive substances permit application head document [Ref 1]. The HPC Environment Case has been maintained and updated since the HPC permit application and one of the aims of the introductory sections of this document (Sections 2, 3 & 4) is demonstrate that its adaptation is suitable for SZC. Within Section 3, SZC site specific issues are considered and proportionately addressed within the Environment Case.

10. Sections 1-5 of this document how the SZC Environment Case was developed building on GDA [Ref 5] and the work done at HPC, to take account of detailed design and further BAT demonstration that has taken place.

Section 6 of this document presents the SZC Environment Case (with regards to the ‘Plant’ aspect, i.e. the Environment Case) in full.

11. SZC Co. acknowledges that the demonstration and application of BAT has broad coverage, implemented through the RSR environmental permit’s limitations and conditions. This document is the primary means through which the key aspects associated with the demonstration of the application of BAT are covered.

12. Techniques that are implemented to deliver BAT and to dispose of waste must be maintained and monitored to demonstrate that they are performing as expected. There is a requirement as part of the RSR permit that techniques adopted to undertake sampling, measurements, analysis, tests and calculation that demonstrate compliance with formal conditions are also BAT. This requirement extends to both engineered and management systems, notably:

    - The application of BAT specifically related to sampling, monitoring, analysis, calculations of samples for liquid and gaseous discharges is covered in RSR Permit Application Support Documents C.1 (Plant Monitoring) [Ref 6] and C.2 (Environmental Monitoring) [Ref 7].
    - The application of BAT specifically related to sampling, monitoring, analysis, calculations of samples for solid waste disposal is covered in RSR Permit Application Support Document A.2 (Integrated Radioactive Waste Strategy) [Ref 8].
    - The demonstration and application of BAT to management arrangements is covered in the head document [Ref 1].

1.3 Replication Strategy

13. As far as is practical the design of SZC will replicate that of HPC. The SZC nuclear island will be identical to that for HPC, therefore the radioactive waste generation will be the same including the means to minimise the amount of radioactive waste produced as well as the storage, treatment, abatement and monitoring of radioactive wastes.

14. A consistent state of the UK EPR^{TM} design process is delivered using the concept of RCs. To enable consistency between HPC and SZC, the initial reference configuration for SZC is based on the most recent for HPC, RC2, this includes a list of all design changes to support implementation and related studies, including hazard and fault studies, to deliver consistent state 2 (CS2) for HPC. CS2 will be adopted by SZC Co. as it is formed as the consistent state replication baseline for SZC.

15. In order to maintain consistency between the HPC and SZC designs, the initial reference configuration for the SZC project is based on RC2 for HPC, known for SZC as RC0. As a result, all system, structure and component codes are retained between HPC and SZC. A review of the applicability of the design into SZC has been undertaken, where appropriate BAT justification of the SZC design will rely on available evidence from the HPC project, where there are no site-specific impacts, and there have been no significant changes to the design. A second reference configuration is planned for SZC (RC1) to capture all changes to the SZC RC0 design as a result of SZC site-specificities and to allow incorporation, as appropriate, of ongoing HPC design changes and development. These will be subject to a formal design change process by SZC Co. and will be suitably screened for environmental impact/impact on permit compliance and require a risk-informed and proportionate justification, it is expected that only mandatory site-specific changes or those resulting in a significant benefit will be incorporated in order to ensure transferable learning and practice between HPC and SZC as a series of UK EPR^{TM} stations.

16. Documents from NNB GenCo (HPC) that predate RC2 and are incorporated into the design for SZC and have been accepted as part of the replication strategy. Any subsequent changes would be considered by SZC before being accepted into the SZC design.

1.4 Definitions

1.4.1 Building Codes

Term / Abbreviation	**Definition**
HCA	Outfall Pond Building
HGQ	Effluent Gallery
HGV	Nuclear Auxiliary Building – Tanks Liaison Gallery
HGY	Demineralisation Station Gallery
HHI	Intermediate Level Waste Interim Storage Facility
HHK	Interim Spent Fuel Store
HK	Fuel Building
HL	Safeguard Building
HM	Turbine Hall
HN	Nuclear Auxiliary Building
HQA*	Radioactive Waste Storage Building
HQB*	Radioactive Waste Process Building
HQC*	Radioactive Waste Preparation Building for Unit 2
HVD	Facilities for Decontamination Building
HVL	Hot Laundry Building
HW	Access Building
HR	Reactor Building
HXA	KER, TER, SEK & PTR Tank Building
HXO	Attenuation Pond

*HQA/HQB/HQC are referred to elsewhere as the Effluent Treatment Buildings

1.4.2 System Codes

Term / Abbreviation*	**Definition**
APG	Steam Generator Blowdown System
CVI	Condenser Vacuum
DWK	Fuel Building Ventilation System
DWL	Controlled Safeguards Building Ventilation System
DWN	Nuclear Auxiliary Building Ventilation System
DWQ	Effluent Treatment Building Ventilation System
DWW	Access Building Ventilation System
EBA	Containment Sweep Ventilation System
EDE	Annulus Ventilation System

Term / Abbreviation*	Definition
EPP	Leak Rate Control and Testing System
EVF	Reactor Building Internal Particulate and Iodine Filtration System
EVR	Containment Cooling Ventilation System
EVU	Containment Heat Removal System
IRWST	In-Containment Refuelling Water Storage Tank
JPI	(Nuclear Island) Fire Fighting System
KER	Liquid Radwaste Monitoring and Discharge System
KRT	Plant Radiation Monitoring System
NSSS	Nuclear Steam Supply System
PTR	Fuel Pool Cooling System
RCP	Reactor Coolant System
RCV	Chemical and Volume Control System
REA	Reactor Boron Water Make-Up System
REN	Nuclear Sampling System
RES	Nuclear Sampling System – Secondary Side
RIS	Safety Injection System
RPE	Nuclear Vent and Drain System
RRI	Component Cooling Water System
SAT	Service Compressed Air Distribution System
SBE	Hot Decontamination System
SEC	Essential Service Water System
SED	Demineralised Water Distribution System
SEH	Collection and Storage of Oils and Hydrocarbon Effluents
SEK	Site Liquid Waste Discharge System
SGN	Nitrogen Distribution System
TEG	Gaseous Waste Treatment System
TEN	Effluent Treatment Building Sampling System
TEP	Coolant Storage and Treatment System
TER	Additional Liquid Waste Discharge System
TES	Solid Waste Treatment System
TEU	Liquid Waste Processing System
VVP	Main Steam System

* In the text some system codes are prefixed with ‘2’ or ‘9’ this indicates the scope of the system with regards to serving individual or both reactor units. The ‘9’ refers to a shared system. The ‘2’ refers to separate systems for each unit.

1.4.3 Abbreviations

Term / Abbreviation	Definition
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AP	Advanced Process
BAT	Best Available Techniques
BES	Baseline Environmental Summary
BWR	Boiling Water Reactor
CN	Condensate Nuclei
CPP	Reactor Coolant Pressure Boundary
CRDM	Control Rod Drive Mechanism
CREDO	Chemical and Radiochemical EPR^{TM} Design Optimisation
CVVT	Constant Volume Variable Time
DAW	Dry Active Waste
DECC	Department of Energy and Climate Change
DF	Decontamination Factor
DOP	Dispersed Oil Particle
EARWG	Environment Agencies Requirements Working Group
EDS	Environmental Design Summary
EFPD	Equivalent Fuel Power Day
EoG	End of Generation
EOS	Environmental Optimisation Studies
EP	Electro Polishing
EPE	Environmental Protection Equipment
EPF	Environmental Protection Function
EPRI	Electric Power Research Institute
ERMS	Environment Radioactivity Monitoring Strategy
ETC-C	EPR^{TM} Technical Code for Civil Works
FA3	Flamanville 3 Nuclear Power Plant
FD	Floor Drain[1]
FPS	Flow Proportional Sampler
FRP	Fuel Reliability Program
GDA	Generic Design Assessment
GDAF	GDA Assessment Findings

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[1] Note there are 3 separate floor drain lines – FD1, FD2 & FD3

Term / Abbreviation	Definition
GDF	Geological Disposal Facility
HEPA	High Efficiency Particulate Air
HF	Human Factors
HPC	Hinkley Point C
HPC IC	Hinkley Point C Information Condition
HVAC	Heating, Ventilation and Air-Conditioning
I&C	Instrumentation & Control
IAEA	International Atomic Energy Agency
IAPWS	International Association for the Properties of Water and Steam
IC	Intelligent Customer
ICOI	Inadequately Conceived or Implemented
ILW	Intermediate Level Waste
KEPE	Key Environmental Protection Equipment
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LoC	Letter of Compliance
LWR	Light Water Reactor
MADA	Multi-Attribute Decision Analysis
MCERTS	(Environment Agency) Monitoring Certification Scheme
MCP	Main Coolant Pump
MCR	Main Control Room
MPC	Multi-Purpose Container
ND	Nominal Diameter
NDA	Nuclear Decommissioning Authority
NNB GenCo (HPC)	NNB Generation Company (HPC) Ltd
NPP	Nuclear Power Plants
OEF	Operating Experience Feedback
ONR	Office for Nuclear Regulation
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
ppm	Parts per million
PWR	Pressurised Water Reactor
QA	Quality Assurance
QNL	Quarterly Notification Level
R&D	Research & Development

Term / Abbreviation	Definition
RASCAR	Radioactive Substances Compliance Report
RD	Responsible Designer
ROV	Remote Operated Vehicle
RSR	Radioactive Substances Regulations
RWM	Radioactive Waste Management Ltd.
SAP	Safety Assessment Principles
SDM	System Design Manual
SFAIRP	So Far As is Reasonably Practicable
SFCTF	Spent Fuel Cask Transfer Facility
SG	Steam Generator
SSC	Structures, Systems and Components
SZB	Sizewell B
SZC	Sizewell C
SZC Co.	NNB Generation Company (SZC) Ltd
TGN	Technical Guidance Note
VCT	Volume Control Tank
VLLW	Very Low Level Waste
WAC	Waste Acceptance Criteria
WANO	World Association of Nuclear Operators

1.5 References

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3.	Radioactive Substances Regulation Environmental Permit Application for Hinkley Point C	NNB-OSL-REP-000169	8.0	EDRMS	NNB GenCo (HPC)
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24.	Hinkley Point C Revised MADA Study for Storage of Spent Fuel	HPC-NNBOSL-U9-000-REP-100009	2.0	EDRMS	NNB GenCo (HPC)
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34.	First approach of actinides speciation in PWR primary coolant conditions for a better understanding of their behaviour	100172813	1.0	EDRMS	NNB GenCo (HPC)
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78.	RC1.2 Environmental Ranking Form CANP0254UK – Reactor coolant pump – Implementation of hydrodynamic seal	100133443	1.0	EDRMS	NNB GenCo (HPC)
79.	NNB Environmental Ranking Form for T1SNEUK10771A – HD seals – TCN668 C Mirror Design Change & complements	100198982	1.0	EDRMS	NNB GenCo (HPC)
80.	BAT assessment for design change T1WIT-UK-10456 – TEG Environmental Protection Robustness	100193866	1.0	EDRMS	NNB GenCo (HPC)
81.	RC2 Environmental Ranking Form T1EIPUK100004 – RPE18VP safety valve gas/liquid discharge management	100193854	1.0	EDRMS	NNB GenCo (HPC)
82.	Transfer of spent resins and liquid effluents through the HGQ gallery	HPC-NNBOSL-U0-000-REP-100006	2.0	EDRMS	NNB GenCo (HPC)
83.	Study for the Management of ILW Resins on the Hinkley Point C Site.	HPC-UK1421-AU-TES-STU-002025	C	EDRMS	Sofinel (now Edvance)
84.	Implementation of DDM CGCA5019UK – Spent Fuel Dry Storage in HK – Addition of racks in star area	HPC-UK4101-AU-ALL-CHR-004584	A	EDRMS	Edvance
85.	Radioactive Liquid Processing Guidelines	100172829	1.0	EDRMS	Electric Power Research Institute
86.	Recent Advances in Water Chemistry Control at US PWRs	100172834	1.0	EDRMS	Electric Power Research Institute
87.	Nuclear New Build Design Authority Decision Note for the Choice of Secondary Circuit and Demineralised Water Chemical Conditioning	100149633	1.0	EDRMS	NNB GenCo (HPC)
88.	Screening Form ECN F3139	100188837	1.0	EDRMS	NNB GenCo (HPC)
89.	TEU P3 – Sizing of the system and its components	HPC-UK1421-U9-TEU-SDM-002471	B	EDRMS	Edvance

Ref	Title	Document No.	Version No.	Location	Author
90.	Environmental Optimisation Study (EOS) - Justification of the selection of demineralisation media and filters porosity in the nuclear island systems	HPC-ECECSX-XX-ALL-NOT-000459	D	EDRMS	CNEN
91.	Additional liquid Waste Discharge System (TER)	HPC-UK1421-AU-TER-SDM-007071	B	EDRMS	Edvance
92.	TEU P2 – System Operation	HPC-UK1421-U9-TEU-SDM-007162	C	EDRMS	Edvance
93.	Substantiation of the number and sizing of KER storage tanks for HPC	HPC-CNENXX-KER-STU-000001	A	EDRMS	CNEN
94.	Substantiation of the number and sizing of TER storage tanks for HPC	100148484	1.0	EDRMS	CNEN
95.	UK EPR – Consumable chemicals' specifications (PMUC) for equipment	UKX-EDECME-XX-000-SPE-000055	5.0	EDRMS	Edvance
96.	EDECME120671 - Recommended Usage Guide – Operating demineralisers in PWR plants	100148486	1.0	EDRMS	CEIDRE
97.	UK6321 – Datasheets of tanks and demineralisers of BNI	HPC-ECEMAX-AU-ALL-NOT-000516	E	EDRMS	Edvance
98.	MODEM report for the TEU evaporator	HPC-NNBOSL-XX-000-REP-100284	2.0	EDRMS	CNEN/HPC
99.	Decision Document and Authorisations for future regulation of disposals of radioactive waste under the Radioactive Substances Act 1993 at British Energy Generation Limited's nuclear sites	100172833	1.0	EDRMS	Environment Agency
100.	Generic design assessment UK EPR nuclear power plant design by AREVA NP SAS and Electricité de France SA	100172831	1.0	EDRMS	Environment Agency
101.	Technical Review #0275 CANP0233UK	100101857	1.0	EDRMS	NNB GenCo (HPC)
102.	Technical Work Request: BAT assessments for DDR, A2/B and R0C V3-V2 modifications	HPC-NNBOSL-XX-000-TQY-000136	1.0	EDRMS	CNEN
103.	Effluent Release Options from Nuclear Installations	100172798	1.0	EDRMS	Organisation for Economic Co-operation and Development

Ref	Title	Document No.	Version No.	Location	Author
104.	Combined methods for liquid radioactive waste treatment: Final report of a co-ordinated research project 1997–2001	IAEA-TECDOC-1336	-	https://www-pub.iaea.org/MTCD/publications/PDF/te_1336_web.pdf Last accessed: 24/02/2020	International Atomic Energy Agency
105.	Report to provide the design of the liquid waste processing system to meet information condition 10 of the HPC RSR permit EPR/ZP3690SY	100158819	1.0	EDRMS	NNB GenCo (HPC)
106.	EARWG - Best Practise in Waste Minimisation	-	-	NDA estate, The Hub	NDA
107.	Preliminary sizing for the EPR UK Liquid waste processing system (TEU) demineralisation station	100148484	1.0	EDRMS	CNEN
108.	Assessment of the 4th Round of Reporting on the Implementation of PARCOM Recommendation 91/4 on Radioactive Discharges	100172801	1.0	EDRMS	Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)
109.	GDA UK EPR – Integrated Waste Strategy Document	100172800	1.0	EDRMS	EDF/AREVA/NP
110.	BAT/ALARP optioneering report - Radioactive effluent filters (RCV, PTR, RPE) performance (DF) monitoring	HPC-ECECSX-AU-HNX-NOT-000417	A	EDRMS	CNEN
111.	Technical Review-0167 RCV Cartridge Filters: Modification of the Cartridge Length	100108925	1.0	EDRMS	NNB GenCo (HPC)
112.	Report to provide the detailed design proposals for the liquid waste processing system to meet information condition 9 of the HPC RSR permit EPR/ZP3690SY	100155998	2.0	EDRMS	NNB GenCo (HPC)
113.	UK6301 – Filters - Environmental Design Summary	HPC-UK6301-U0-ALL-REP-100011	G	EDRMS	Pall
114.	9SBE Baseline Environmental Summary	HPC-UK1421-U9-SBE-STU-201124	C	EDRMS	Edvance
115.	TCN-371: New vent lines from RCV [CVCS] to RPE1 to mitigate H2 risk	UK4101-COR-BFP-100581-BEOL	A	EDRMS	AREVA
116.	ECEF050113 A - Design study and validation of the principle characteristics of the spent effluent treatment system TEU	100148482	1.0	EDRMS	CNEN
117.	Reference number not used	-	-	-	-
118.	EOS - BAT optioneering - TEU distillates monitoring	HPC-ECECSX-U9-TEU-RES-000334	A	EDRMS	CNEN

Ref	Title	Document No.	Version No.	Location	Author
119.	Stage 2 Environmental Optimisation Study for the specification of equipment used for liquid effluent monitoring	100190649	1.0	EDRMS	NNB GenCo (HPC)
120.	Reference number not used	-	-	-	-
121.	CFSE0529 'Diaphragms added on mixing and filtering lines of TEU storage tanks'	CFSE0529UK	1.0	EDRMS	CNEN
122.	BDR Screening Forms - CCSE0038UK	100118768	1.0	EDRMS	NNB GenCo (HPC)
123.	EnvRankForm_RC1.2_design of new building HK_CIG5004UK.doc	100126584	1.0	EDRMS	NNB GenCo (HPC)
124.	BAT Form for CIG5004UK	100144060	1.0	EDRMS	NNB GenCo (HPC)
125.	RC2 Environmental Ranking Form T2WIT-10603 – Update of the 9KER/SEK final discharge valve closure logic	100193876	1.0	EDRMS	NNB GenCo (HPC)
126.	Abatement of Radioactive Releases to Water from Nuclear Facilities. Technical Guidance Note (Abatement). A6.	100172855	1.0	EDRMS	Environment Agency
127.	Treatment of Radioactively Contaminated Gases in Nuclear Power Plants with Light Water Reactors	KTA 3605	-	http://www.kta-gs.de/e/standards/3600/3605_engl_2017_11.pdf last accessed: 25/02/2020	Nuclear Safety Standards Commission
128.	TEG System Design Manual P2 – System Operation	HPC-UK1421-AU-TEG-SDM-002187	F	EDRMS	Edvance
129.	BAT Assessment of TEG modifications (CCSE5033) related to Technical Work Request HPC-NNBOSL-XX-00-TQY-000136	UK/ESW/2015/EN/0504	A	EDRMS	Sofinel (Now Edvance)
130.	Charcoal and Charcoal Challenge Material – BAT Assessment – Transverse Environmental Study	HPC-UK1421-AU-ALL-REP-201140	C	EDRMS	Edvance
131.	Technical Review-0303 - Modification of the behaviour of the TEG system delay line in order to meet the environment criteria	100123203	1.0	EDRMS	NNB GenCo (HPC)
132.	MODEM Report 2013-45: TEG delay bed MODEM #35	NNB-202-REP-000273	D	EDRMS	Arias, N.
133.	Optioneering of tritium management support	100133001	1.0	TBC	Sofinel (Now Edvance)
134.	ICRP, 1983. Radionuclide Transformations - Energy and Intensity of Emissions.	ICRP Publication 38. Ann. ICRP 11-13.	-	https://journals.sagepub.com/toc/anib/10/4 Last accessed: 24/02/2020	ICRP

Ref	Title	Document No.	Version No.	Location	Author
135.	Design Change Reporting Form CCSE5031UK	100103425	1.0	EDRMS	NNB GenCo (HPC)
136.	Technical Guidance Note (Abatement) A05 - Abatement of Atmospheric Radioactive Releases from Nuclear Facilities	100172817	1.0	EDRMS	Environment Agency
137.	An Aid to the Design of the Ventilation of Radioactive Areas	100172810	1.0	EDRMS	Nuclear Ventilation Forum
138.	Reference number not used	-	-	-	-
139.	Technical Review-0015_Pre-filter on the EDE System	100120496	1.0	EDRMS	NNB GenCo (HPC)
140.	Technical Review-0061: Modifications to Fuel Building Ventilation System (DWK) in order to maintain depression of the areas containing radioactive iodine	100123045	1.0	EDRMS	NNB GenCo (HPC)
141.	Environmental Optimisation Study for HVAC HEPA filter and Iodine Trap efficiency testing.	HPC-UK1421-AU-DWN-ANA-200671	B	EDRMS	Sofinel (Now Edvance)
142.	IAEA Technical Report 421	N/A	-	https://www-pub.iaea.org/MTCD/Publications/PDF/TRS421_web.pdf Last accessed: 24/02/2020	International Atomic Energy Agency
143.	Journal of Nuclear Science Technology 37	ISSN: 1738-5733	-	-	-
144.	Review of ILW Decay Storage Strategy	HPC-NNBOSL-XX-000-STR-100004	1.0	EDRMS	NNB GenCo (HPC)
145.	Calculation Sheet – Operational ILW radiological fingerprint and decay storage proportions	HPC-NNBOSL-U9-TES-CAL-100001	12.0	EDRMS	Nuclear Technologies
146.	Reference number not used				
147.	Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom	100172807	1.0	EDRMS	Defra/ DTI
148.	LLW Strategic Review	100172804	1.0	EDRMS	Low Level Waste Repository / Nuclear Decommissioning Authority
149.	Hinkley Point C Reactor Dismantling Waste Optioneering Report	HPC-HPC-NNBGEN-U9-000-REP-100010	2.0	EDRMS	Cavendish Nuclear

Ref	Title	Document No.	Version No.	Location	Author
150.	Intermediate Level Waste Management - Optioneering for decay storage	ECUK121061	A	EDRMS	CNEN
151.	ECEF072084 - Flamanville 3 Summary Report: specific design provisions relating to EPR chemistry	100148483	1.0	EDRMS	CNEN
152.	UK EPR - BAT/ALARP study for the choice of wet sludge and evaporator concentrates treatment	UKX-ECECSX-XX-000-RES-000187	B	EDRMS	CNEN
153.	Integrated Waste Management: Overview	3.18-2 [SMS/TS] Doc ID: 11636153	-	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/457025/Integrated_Waste_Management_Overview.pdf Last accessed: 24/02/2020	Nuclear Decommissioning Authority
154.	Identification of the preferred option for the storage and disposal of non-fuel core components	HPC-UKX-NNBGEN-U9-000-REP-100000	2.0	EDRMS	NNB GenCo (HPC)
155.	GDA disposability assessment	NXA/10747397	-	http://www.epr-reactor.co.uk/ssmod/liblocal/docs/Supporting%20Documents/GDA%20Disposability%20Assessment%20of%20Wastes%20and%20Spent%20Fuel%20Part%201.pdf Last accessed: 24/02/2020	Nuclear Decommissioning Authority
156.	Conceptual LoC -ILW	HPC-3RDREG-XX-000-REP-100003	1.0	EDRMS	NNB GenCo (HPC)
157.	BAT Assessment for the Minimisation of Gaseous Discharges of Tritium to Air	HPC-CNENXX-XX-ALL-NOT-202781	B	EDRMS	Edvance
158.	Reference number not used	-	-	-	-
159.	RC1 MODIFICATION BAT FORMS	HPC-ETDPNN-U0-ALL-NOT-000230	A	EDRMS	CNEPE
160.	Justification of Stack Height for SZC	100101549	1.0	EDRMS	Radiological Protection Supervisors

Ref	Title	Document No.	Version No.	Location	Author
161.	BAT Optioneering of Additional Monitoring Provisions for Systems Contributing to NAB Stack Discharges on the HPC EPR	HPC-ECECSX-XX-ALL-NOT-000411	C	EDRMS	CNEN
162.	Environmental Design Summary and BAT Case Justification For HPC - HI-2167268	HPC-GEN442-U9-HKX-REP-100005	7.0	EDRMS	Holtec
163.	Radiological Monitoring Technical Guidance Note 1 - Standardised Reporting of Radioactive Discharges from Nuclear Sites	May 2010	-	-	Environment Agency
164.	Commission Recommendation of 18 December 2003 on standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation	(2004/2/Euratom)	-	https://ec.europa.eu/energy/sites/ener/files/documents/2004_2_en.pdf Last accessed: 25/02/2020	EURATOM
165.	BAT Optioneering of the Design of NAB Stack Discharge Monitoring Provisions on the HPC EPR	HPC-ECECSX-XX-ALL-NOT-000412	D	EDRMS	CNEN
166.	RC1.2 Environmental Ranking Form - CGCA5015UK	100126522	1.0	EDRMS	NNB GenCo (HPC)
167.	Technical specification of the HHI: intermediate Level Waste Storage Facility	HPC-ECEIGX-U9-HHI-SPE-001270	F	EDRMS	Edvance
168.	Monitoring of radioactive discharges to atmosphere from nuclear facilities.	Technical Guidance 245_17	-	-	Environment Agency
169.	Environmental Optimisation Study Stage 1 (EOS1) – Monitoring Design and Sampling Techniques for Radioactive Gaseous Discharges from Hinkley Point C	HPC-ECECSX-XX-ALL-NOT-000410	B	EDRMS	CNEN
170.	RC2 Environmental Ranking Form – CCSE5070UK – Addition of new KRT sampling points for monitoring contributions to stack discharges	100149612	1.0	EDRMS	NNB GenCo (HPC)
171.	Report to demonstrate that the sampling of discharges have been adequately considered in the design of plant to meet information condition 4 of the HPC RSR permit EPR/ZP3690SY	100146597	2.0	EDRMS	NNB GenCo (HPC)
172.	Environment Agency Technical Guidance Note – M11: Monitoring of Radioactive Releases to Atmosphere from Nuclear Facilities	TGN M11	-	N/A	Environment Agency
173.	Measuring Radioactivity in Gaseous and Liquid Effluent. French Standard M60-825 (2012)	M60-825	-	N/A	ISO- NF
174.	NNB BAT/EOS List/Open points Tracker	100124462	LIVE	EDRMS	NNB GenCo (HPC)
175.	ENG 6.01. Engineering rules for design, layout and PDMS modelling of piping and fittings.	HPC-UK1421-AU-ALL-NOT-200674	B	EDRMS	Edvance

Ref	Title	Document No.	Version No.	Location	Author
176.	Transfer procedure ENG2.64 – installation guide: taking into account human factors	HPC-UK1421-AU-ALL-NOT-200674	B	EDRMS	Edvance
177.	HN stack contract UK2741 specification	HPC-UK1421-AU-HKX-SPT-002309	H	EDRMS	Edvance
178.	Minimum requirements for the self-monitoring of flow	LIT 6695	-	https://www.gov.uk/government/publications/mcerts-minimum-requirements-for-the-self-monitoring-of-effluent-flow Last Accessed: 25/02/2020	Environment Agency
179.	Environmental Optimisation Study Stage 1 (EOS1) - Monitoring Design and Sampling Techniques for In-process Radioactive Gaseous Effluents at Hinkley Point C	HPC-ECECSX-XX-ALL-NOT-000409	D-	EDRMS	CNEN
180.	Environmental Optimisation Study Stage 1 (EOS1) - Monitoring Design and Sampling Techniques for In-process Radioactive Liquid Effluents at Hinkley Point C	HPC-ECECSX-XX-ALL-NOT-000392	C	EDRMS	CNEN
181.	Environmental Optimisation Study Stage 1 (EOS1) – Monitoring Design and Sampling Techniques for Radioactive Liquid Discharges from Hinkley Point C	HPC-ECECSX-XX-ALL-NOT-000402	C	EDRMS	CNEN
182.	BAT assessment of the height and spacing of KRT sampling lines at the NAB stack	HPC-CNENXX-AU-KRT-NOT-203623	A	EDRMS	Edvance
183.	BAT/ALARP Analysis for H-3/C-14 Sampling of the TEG Recombiner for HPC	HPC-ECECSX-XX-ALL -NOT-000413	B	EDRMS	CNEN
184.	BAT/ALARP optioneering report - TEP6 degasser performance (DF) monitoring	HPC-ECECSX-AU-TEP-NOT-000416	B	EDRMS	CNEN
185.	Assessment of HPC EPR Monitoring Design and Sampling Techniques for In-process, Radioactive, Gaseous Systems on the HPC EPR Against BAT Criteria and Regulatory Standards/Guidance	HPC-CNENXX-XX-ALL-NOT-200311	B	EDRMS	CNEN
186.	SDM - KRT– P2 System Operation	HPC-ECECSX-AU-KRT-SDM-001279	C	EDRMS	Edvance
187.	Monitoring of Radioactive Releases to Water from Nuclear Facilities, Technical Guidance Note, M12.	TGN M12	-	Web	Environment Agency

Ref	Title	Document No.	Version No.	Location	Author
188.	BS EN 16479 : Water Quality. Performance requirements and conformity test procedures for water monitoring equipment. Automatic sampling devices.	BS EN 16479	-	https://shop.bsigroup.com/ProductDetail/?pid=000000000030246664 Last accessed: 25/02/2020	British Standards
189.	UK EPR – Sampling radioactive liquid discharges: a BAT assessment	HPC-EDLCHM-A1-000-RET-000013	A	EDRMS	CEIDRE
190.	Technical Guidance Note (Monitoring) M18 – Monitoring of Discharges to water and sewer	TGN M18 6.0	-	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/646803/LIT_6898.pdf Last accessed: 25/02/2020	Environment Agency
191.	Baseline Environmental Summary for the KER/TER/SEK tanks building (HXA)	HPC-UK1421-U9-HXA-NOT-201135	B	EDRMS	Edvance
192.	ASTM D3370. Sampling practices for sampling water from closed conduits.	ASTM D3370	-	https://www.astm.org/Standards/D3370.htm Last accessed: 25/02/2020	American Society for Testing and Materials
193.	MCERTS: Performance Standards and test procedures for Continuous water sampling equipment. Part 1 – Performance standards and test procedures for automatic water sampling equipment	LIT 4352	-	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/612608/LIT_4352.pdf Last accessed: 25/02/2020	Environment Agency
194.	Definition of Piping Specifications	HPC-UK1421-AU-ALL-NOT-201027	F	EDRMS	Edvance
195.	ENG2-82: Functional Sizing Guidelines for components of water systems	ECECS120796	3.0	EDRMS	Edvance
196.	Liquid Radwaste monitoring and discharge system (KER). System Operation	HPC-UK1421-AU-KER-SDM-007081	B	EDRMS	Edvance
197.	Liquid Radwaste monitoring and discharge system (KER). Sizing of the System and its components	HPC-UK1421-AU-KER-SDM-002106	B	EDRMS	Edvance
198.	9SBE (Site Laundry and Hot Decontamination System) optioneering study	HPC-UK1421-U9-SBE-STU-201035	B	EDRMS	Sofinel (Now Edvance)

Ref	Title	Document No.	Version No.	Location	Author
199.	RSR Assessment for HPC EPR monitoring design for in-process radioactive liquid effluents against BAT criteria and regulatory/standards requirements – RSR CP4	HPC-ECECSX-XX-ALL-NOT-000486	1.0	EDRMS	CNEN
200.	UK EPR – Sampling liquid radioactive in-process effluents: a BAT assessment	HPC-EDLCHM-U1-000-RET-000015	B	EDRMS	CEIDRE
201.	Activity Monitoring of Radioactive Liquid In-Process Effluents and Discharges: a technical assessment	HPC-EDLCHM-XX-000-RET-000023	A	EDRMS	CEIDRE
202.	ALARP REPORT: REN SAMPLING BOX ROOM	100133272	1.0	EDRMS	NNB GenCo (HPC)
203.	HPC Environmental Optimisation Study (EOS) – characterisation and assessment of spent APG resins	HPC-EDLCHM-XX-000-RET-000018	A	EDRMS	CEIDRE
204.	HPC Environmental Optimisation Study (EOS) – Sampling and Measuring Activity of HEPA filters: a technical assessment	HPC-EDLCHM-XX-000-RET-000019	C	EDRMS	CEIDRE
205.	HPC Environmental Optimisation Study (EOS) – Sampling and Measuring Activity in charcoal filters/iodine traps: a technical assessment	HPC-EDLCHM-XX-000-RET-000020	C	EDRMS	CEIDRE
206.	HPC Environmental Optimisation Study (EOS) – Characterisation of Radioactive Sludge	HPC-EDLCHM-XX-000-RET-000021	C	EDRMS	CEIDRE
207.	Sampling and Measuring Activity in Oils and Solvents: a technical assessment	HPC-EDLCHM-XX-000-RET-000022	C	EDRMS	CEIDRE
208.	HPC Environmental Optimisation Study (EOS) – Sampling and Measuring Activity of Dry active and Metallic Waste: a technical assessment	HPC-EDLCHM-XX-000-RET-000025	C	EDRMS	CEIDRE
209.	HPC Environmental Optimisation Study (EOS) – Sampling and Measuring Activity in Active Resins: a technical assessment	HPC-EDLCHM-XX-000-RET-000026	C	EDRMS	CEIDRE
210.	HPC Environmental Optimisation Study (EOS) – Sampling and Measuring Activity in Concentrates: a technical assessment	HPC-EDLCHM-XX-000-RET-000027	B	EDRMS	CEIDRE

Ref	Title	Document No.	Version No.	Location	Author
211.	HPC Environmental Optimisation Study (EOS) – Sampling and Measuring Activity in Water Filters: a technical assessment	HPC-EDLCHM-XX-000-RET-000028	D	EDRMS	CEIDRE
212.	BAT demonstration for hydrazine measurement	HPC-EDLCHM-XX-000-RET-000024	B	EDRMS	CEIDRE
213.	HPC Environmental Radioactivity Monitoring Strategy	100178923	2.0	EDRMS	NNB GenCo (HPC)
214.	Radiological Monitoring Technical Guidance Note 2: Environmental Radiological Monitoring	N/A	-	EDRMS	Environment Agency, Food Standards Agency, Office for Nuclear Regulation
215.	Baseline Environmental Summary –2/9RPE	HPC-UK1421-U9-RPE-NOT-201138	A	EDRMS	Edvance
216.	Baseline Environmental Summary for 9PTR	HPC-CNENXX-U9-PTR-STU-202807	A	EDRMS	CNEN
217.	Screening Form_CCSE0011 - Implement deluge system in place of sprinkler system	100188839	1.0	EDRMS	NNB GenCo (HPC)
218.	HEPA filters type assessment	100208090	1.0	EDRMS	Edvance
219.	Best Available Technique (BAT) analysis for the minimisation of particulate matter associated with aqueous discharge systems (KER/TER/9SEK)	HPC-UK1421-AU-TER-ANA-200219	B	EDRMS	NNB GenCo (HPC)

2 Key Considerations for Demonstration of BAT for SZC

17. The Environment Agency (EA) defines BAT in its Principles of Optimisation guidance [Ref 9] on the subject as:

> *"…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)."*

18. The individual terms are defined as:

- 'best' shall mean most effective in achieving a high general level of protection of the environment as a whole.
- 'available' techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator; and
- 'techniques' shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

19. RSR Environmental Permit includes a formal definition of the term "best available techniques" as the:

> *"latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste. In determining whether a set of processes, facilities and methods of operation constitute BAT in general or individual cases, special consideration shall be given to:*

- *comparable processes, facilities or methods of operation which have recently been successfully tried out;*
- *technological advances and changes in scientific knowledge and understanding;*
- *the economic feasibility of such techniques;*
- *time limits for installation in both new and existing plants; and*
- *the nature and volume of the discharges and emissions concerned."*

20. It therefore follows that what is "best available techniques" for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding, including whether a technique is commercially available to the operator.

21. The following sections will set out key considerations in demonstrating BAT for the SZC project, and how this has shaped the approach to demonstrating BAT in this document.

2.1 Application of Relevant Good Practice

22. The EA's guidance on optimisation [Ref 9] states that:

> *"In demonstrating BAT, the operator should have regard to the use of standards, guidance and relevant good practice. We expect operators to adopt and implement such standards, guidance and relevant good practice; unless they can justify that alternative measures provide a similar level of protection or performance. This applies to all aspects of operation, including matters such as sampling and monitoring, managements systems, maintenance, record keeping etc.*

> *In general, sources of such guidance and good practice may include:*
>
> - *Government Policy (e.g. UK Discharge Strategy);*
> - *Environment Agency Guidance (including joint guidance with the Health and Safety Executive / Scottish Environment Protection Agency);*
> - *Codes of Practice;*
> - *Standards (whether international or national or trade);*
> - *Company standards/procedures; and*
> - *Working practices, processes and techniques."*
>
> *"Operators may seek to argue that the adoption and implementation of our guidance and relevant good practice represents BAT without the need for more detailed consideration of options appraisal and optimisation. This approach is acceptable providing that the operator demonstrates that the guidance and good practice is relevant and fully applicable to the facility in question. This approach may be adopted for parts of a facility or all of it depending on the guidance available."*

23. SZC Co.'s approach to the application of BAT is consistent with this guidance and takes account of international best practice, standards and guidance. Section 3 describes the process and methodology for the demonstration of BAT for SZC, of which these are important aspects.

2.2 Proportionality in the Assessment of BAT

24. The EA's guidance [Ref 9] also states:

> *"We [the Environment Agency] take a BAT proportionate approach in relation to*
>
> - *the degree of assessment and demonstration we require of operators and undertake ourselves; and*
> - *the techniques we require operators to use."*
>
> *"Consequently, the demonstration of BAT may vary from a detailed study involving options assessment, selection and minimisation for the operation of a nuclear site to a short description of operation in accordance with recognised standards and guidance for a small user. But in all cases the overall assessment process can be described very simply as:*
>
> - *asking if there is anything further that can be done to reduce doses to people; and*
> - *then implementing it unless the associated detriments are grossly disproportionate to the benefits gained.*
>
> *In other words, BAT is the point when the detriments from implementing further techniques become grossly disproportionate to the benefits gained. Such an assessment does not necessarily need complicated cost-benefit analysis. The use of experienced people, ownership, sound judgement and a clear, logical argument will often be sufficient to make a successful case".*

25. The application of proportionality in the assessment of BAT is an important part of the methodology for demonstration of BAT for SZC and is described in Section 1. It enables focus to be placed on those areas which have most impacts, in terms of environmental performance, at the current stage of development of the installation. SZC Co. benefits from the professional experience and judgement of its design team to apply proportionality using a blend of reasoned logical argument and good practice to design modifications for SZC that are not always of the scale requiring a full options assessment/Multi-Attribute Decision Analysis (MADA) approach.

26. The expected dose to a representative member of the public arising from discharges of both gaseous and liquid effluents at the proposed limits from SZC is presented in the RSR Permit Application Support Document D1 [Ref 10] calculated at 13 µSv/yr. To put this into perspective the UK annual average dose to a member from the public from all sources, including natural radiation, is 2,700 µSv/yr [Ref 11]. Moreover, international and UK guidance [Ref 12], [Ref 13] recognises that where doses are below 10 µSv/yr this is generally considered to be below "regulatory concern" where exemption without further consideration can be undertaken. Furthermore, statutory guidance from the former Department of Energy and Climate Change (DECC) [Ref 13] states that below where doses from discharges are 10 µSv/yr this represents an appropriate level of dose, below which the regulator should not pursue further reductions in discharge limits should not be reduced further if the operator is continuing to apply BAT.

27. It is noted that the statutory guidance to regulators states that *"the requirement to minimise discharges through the use of BAT applies at all times and explains that 10 µSv/yr is not a threshold, target or standard below which there is no need to reduce discharges and their impact, where it would otherwise represent BAT to do so".* It is therefore acknowledged that whilst there is no dose limit below which it is not necessary to further demonstrate BAT, the very low impact of SZC on the local environment, at just above the internationally and nationally recognised criteria considered to be below regulatory concern means the impact from SZC is at the lower end of the impact scales which results in application of proportionality being a key requirement is determining BAT.

28. Therefore, the impacts associated with operational discharges from SZC can be considered to be very low, and the time, effort and cost associated with demonstrating BAT should be proportional to the potential benefit that could be achieved.

2.3 Consideration of BAT in the Design Evolution of SZC

29. The legal requirement defined in the Environmental Permitting Regulations is to ensure doses are kept ALARA. This is implemented through the application of BAT. BAT has to balance benefits and detriments to achieve the optimum solution to keep radiological impacts ALARA. In doing this BAT has to take due cognisance of cost in its considerations. Therefore, given the huge amount of work already completed as part of the detailed design for HPC to meet the exacting requirements specified in the UK and the very low radiological impacts associated with the operation it is considered BAT to replicate the HPC design at SZC so far as is reasonably practicable (SFAIRP).

30. All system, structure and components codes are retained from the HPC site in SZC RC0. Where appropriate BAT justification of the SZC design will rely on equivalent evidence from the HPC project, where there are no site-specific considerations, and where there have been no significant changes to the design. Any change to the design is subject to formal design change process and will be suitably screened for environmental impact/impact on permit compliance.

2.4 Use of BAT externally

31. As described within the SZC RSR Permit Application Head Document the replication strategy has been set up with the intention to maximise the series approach to build a series of UK EPR^{TM} Units [Ref 1]. The management arrangements that will ensure BAT is applied throughout the lifecycle of the installation are covered in the Forward Action Plan and Management Arrangements section of the RSR permit application Head Document [Ref 1].

32. SZC Co. will operate the UK EPR^{TM} units at SZC as the owner and will have access to the range and depth of operational experience that resides within EDF. There is extensive review of reactor performance across the EDF fleet, this includes the Pressurised Water Reactor (PWR) at Sizewell B, as well as the other reactor designs

in operation across Europe. When operational data is available this will include the First of a Kind UK EPR^{TM} at HPC, the other EPRs in Europe. In the UK, EDF is the owner and operator of a fleet of reactors (Advanced Gas-Cooled Reactors and one PWR), therefore ensuring consistency and sharing of learning across the fleet is more direct. It is the intention to ensure organisational learning processes and arrangements are in place to share learning across these sites, noting the differences in operators responsible. It is recognised that commonality between installations, particularly regarding the replication strategy for SZC, offers efficiencies in terms of management and safety (including environmental safety). It provides a source of internal benchmarking against which performance, including environmental performance, can be assessed. Common design and application of BAT means experience can be shared to resolve issues and thus optimise performance. Replication and organisational learning also reduces the impacts of uncertainty by ensuring that new approaches are not introduced unless they have been appropriately evaluated. In addition, the applicability of Operating Experience Feedback (OEF) available to SZC via the EPR^{TM} Operators working group is greatly enhanced by commonality of design. It is recognised that there are and will continue to be differences between operators and sites, however, these differences need to be appropriately considered and justified to ensure that the risk of adding in latent errors are minimised, as the impact of a change would need to be carried into the future and could result in different changes or impacts in the future.

33. SZC will take benefit, such as key learning, from the fleet management experience held by EDF in optimising environmental performance. This, together with the proven technology of the PWR and the evolutionary nature of the UK EPR^{TM} design, has resulted in strong emphasis being placed on OEF and relevant good practice in the methodology used to demonstrate BAT for SZC, which is presented in Section 1. SZC Co. retains its Intelligent Customer (IC) role to review and accept/adopt OEF from other operators, and to ensure site specific factors associated with the SZC site have been considered.

3 Development of the SZC Environment Case

34. Optimisation of environmental performance will be undertaken throughout the life-cycle of the new nuclear power station at SZC from design through operations to eventual decommissioning and site restoration. This purpose of this section is to present the structure of the SZC Environment Case, to demonstrate how the contents of the Environment Case have been adapted GDA and from the HPC Environment Case, and how it was ensured that this was appropriate for the SZC project, and that BAT was applied throughout the process.

3.1 Use of Claims, Argument, Evidence Methodology

35. The basis of the methodology for demonstration of BAT is the application of a claims – arguments – evidence approach. The SZC Co. approach is already widely used in the nuclear and other high hazard industries in the preparation of safety cases [Ref 15].

36. The Environment Case provides a documented record of the application of BAT using the terminology of ‘Claims’, ‘Arguments’ and ‘Evidence’, defined as:

- **Claim** – A high-level statement of what is being sought in terms of environmental optimisation. The Claim may be based on a specific permit condition or regulatory requirement.
- **Argument** – An element which contributes to achieving a claim (or claims) and which links the evidence to the claim. This element can be deterministic, qualitative and/or quantitative. The argument contributes to the demonstration that a claim is valid. **Sub-Arguments** have also been incorporated for those elements that are best demonstrated as a group, i.e. if a number of sub-arguments could relate to a particular overarching discharge method (gaseous or liquid) argument;

- **Evidence** – This is used as the basis of the argument i.e. how the argument can be validated and which allows further examination where required. Evidence can be facts, (e.g. based on established scientific principles and prior research or practices elsewhere), or assumptions.

37. The CAE structure has been used for the demonstration of BAT for HPC as well as across large parts of the UK nuclear sector, in safety case management.

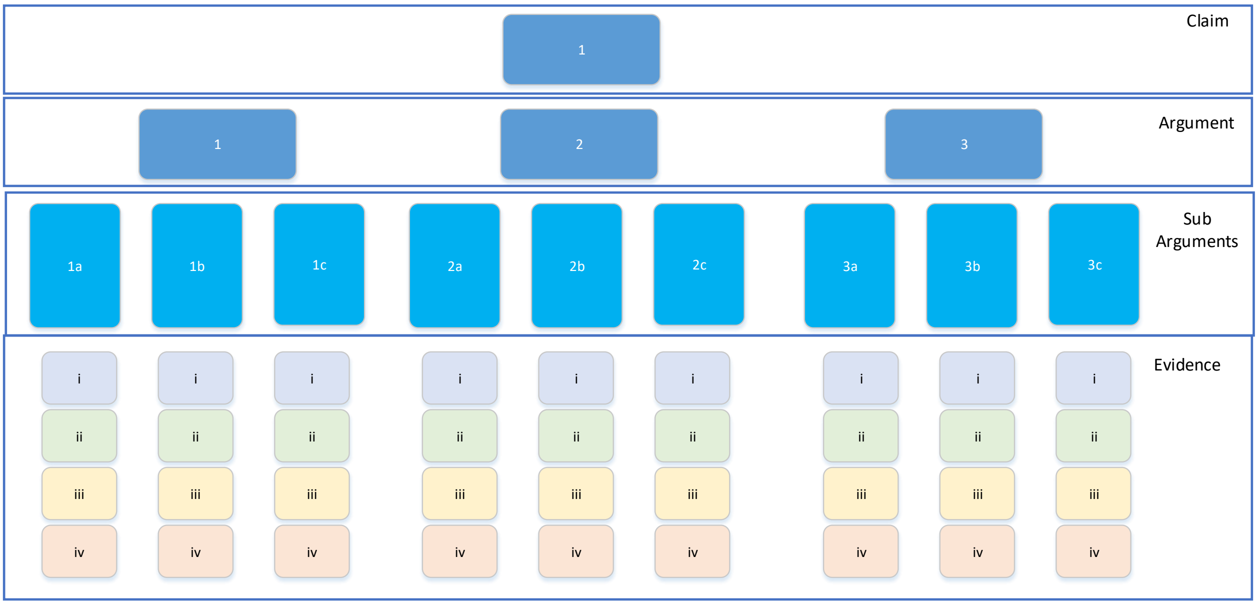

Figure 3-1 Illustration of the Claim-Argument-Evidence method for demonstrating BAT[2]

38. This structured approach is aimed at showing clearly how compliance with the RSR environmental permit requirements is achieved through the mapping of regulatory requirements to claims, supported by arguments which are substantiated by evidence.

39. The case for environmental optimisation can be considered to be:

> *"A documented body of evidence that provides a convincing and valid argument that a system is optimised with respect to environmental performance for the management of radioactive substances at the installation".*

40. To implement a case for the demonstration of BAT the following steps are required:

- production of an explicit set of key claims relating to the installation (system) which underpin the demonstration of BAT. These are based on a review of conditions in the RSR environmental permit and regulatory expectations identified during the GDA process;
- production of a set of arguments (technical elements) that support the claims;
- production, collation and review of evidence that support the arguments and ultimately the claims;
- the statement of any assumptions and judgements underlying the arguments (noting that these can be implicit or explicit); and
- the incorporation of the ability to take account of different viewpoints and levels of detail, which

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[2] The number of arguments, sub-arguments and evidence is for illustrative purposes only and will vary with each of the Claims for the SZC BAT assessment.

will change through the lifecycle of the installation.

41. The following claims have been identified as critical in order to meet the conditions of an RSR environmental permit for SZC. They are:

- Claim 1: SZC Co. shall eliminate or reduce the generation of radioactive waste;
- Claim 2: SZC Co. shall minimise the amount of radioactivity discharged or disposed of to the environment;
- Claim 3: SZC Co. shall minimise the volume of waste disposed to other premises;
- Claim 4: SZC Co. shall minimise the impacts on the environment and members of the public from radioactive waste that is discharged or disposed of to the environment; and
- Claim 5: SZC Co. shall undertake appropriate monitoring to check compliance with the conditions of the RSR permit.

42. These Claims are identical to those in the current HPC Environment Case, this consistency reflects the replication strategy between the two sites[3].

43. Whilst there are no additional claims, there are some additional arguments and evidence associated with the design change modifications that have taken place since the HPC application in 2011 and further detailed design work that has taken place since. Since 2011 the HPC Environment Case has been maintained as a live database, and periodically updated, and the starting point of the SZC Environment Case is the most recent version.

3.2 Evolution of the HPC Environment Case

44. The UK EPR^{TM} GDA, and the HPC RSR permit application provided the foundations of how the application of BAT has been developed for the UK EPR^{TM} design and applied to the SZC design. Since the HPC RSR permit application the UK EPR^{TM} design has developed and the Environment Case has continued to developed since the version provided in the application for HPC.

45. The purpose of this section is to demonstrate how the Environment Case has continued to evolve since the HPC permit application, and how detailed design work undertaken to support the Environment Case since 2011 has been incorporated. This is necessary as the baseline SZC RC0 design is equivalent to the most recent reference configuration of the HPC design (RC2). Section 3.3 demonstrates that the Environment Case is suitable for adaptation for SZC and identifies any site-specific aspects that require further consideration.

46. The Environment Case has undergone continual development over time taking account of periodic reviews of the in line with design freeze or other key project milestones. It is anticipated that key elements of the evidence presented will continue to evolve as the focus moves from design and specification, through construction and commissioning to operation and ultimately to decommissioning and site restoration.

47. When developing the environment case for the UK EPR^{TM} the main steps associated with the application of BAT for individual techniques are:

- **Develop.** Explore the techniques available and determine the contribution that they will make to

---

[3] The final claim regarding monitoring was added to the HPC Environment Case following HPC RSR Permit grant, therefore the claims presented here are not identical to the HPC RSR Permit Application [Ref 3]. It is also noted that between the HPC and SZC Environment Case, there is an inconsistency of numbering. Due to the Environment Case management system at HPC, the monitoring claim for NNB GenCo (HPC) is currently recorded as Claim 6, with no entry for Claim 5. This does not impact the content of the claim.

optimising environmental performance. This is expected to draw heavily on the evolutionary nature of the UK EPR^{TM} design and associated operational experience from the EDF fleet of nuclear reactors.

- **Specify.** Apply decision-making process to select the technique(s) and specify accordingly;
- **Implement.** Undertake activities to implement specified techniques;
- **Verify**. A check is undertaken to verify that the chosen technique has been implemented in accordance with the specification;
- **Review.** The performance of the chosen technique is reviewed to ascertain the degree to which it meets expectations. This in turn, is fed back into organisational learning and management.

48. The Environment Case for the HPC project has been developed according to these steps and as such it is recognised that, given the replication strategy, the design is at an advanced stage where there are limited opportunities for further development of design aspects for SZC. It is recognised that in order to adopt much of the supporting work of the HPC project for SZC, rather than initial development of the design, the ‘review’ step is key to ensuring that the evidence underpinning the HPC Environment Case is suitable for SZC.

49. For the development of SZC, the steps outlined above have not been undertaken discretely. For the most part, where evidence underpinning the HPC design is mature, it has been confirmed that it is appropriate for adoption for SZC. Site specific aspects unique to SZC where further development may be required are summarised in section 3.3, with references to the specific areas of the Environment Case where these are considered. Ensuring the benefits from the replication strategy will be a key consideration when reviewing any future design changes for both HPC and SZC projects.

50. The procurement process will need to take account of the requirements associated with the application and demonstration of BAT. In some cases, where “design and build” is required this will include the requirement to provide sufficient and reasonable evidence to support the Environment Case. The specification step is an essential part of the procurement process. During the manufacturing process of components there will be where applicable acceptance criteria and validation inspections. Evidence of these acceptance criteria will be used to verify the components procured. Where possible, given the considerable effort invested into the procurement process for the HPC project, the replication strategy will be will be applied to procurement activities. For the SZC project, where there will be benefit to consistency between procurement specifications on both projects.

51. Similarly, it will be largely during the construction and commissioning phases of the project that the ‘implementation’ and ‘verification’ steps outlined above will take place. During construction it is key to ensure that proper processes are in place to ensure that the design, which has been demonstrated as BAT, is successfully implemented, and that changes to the design, or implementation of the design, are controlled and that BAT continues to be applied. The processes to be applied to manage change on the SZC project are detailed in the SZC permit application head document [Ref 1].

52. Prior to the commissioning phase of the project, it is necessary to identify all areas for which commissioning activities will be required in order to verify that the design as built represents BAT, and will be able to fulfil the claims made against it in the environment case.

53. Forward actions and future BAT assessments that are identified in this document will be formally captured and managed via the open point register [Ref 16]. Open points in this register are assessed for risk and significance, and reviewed at quarterly open point meetings. The register also includes a list of all completed and planned BAT assessments or related deliverables. This describes the long term nature of SZC Co.’s commitment to the

application of BAT, and ensures that open points identified at any of the steps outlined above, are tracked through the project lifecycle until the appropriate stage for them to be addressed.

54. The development of an integrated project programme that includes the phases, themes and steps identified above necessary for the timely and appropriate implementation of BAT for the SZC facilities is recognised as an important next step. The arrangements in place to ensure that the above is implemented on the SZC project are set out in the management arrangements section of the permit application head document [Ref 1].

55. BAT is therefore aligned with each stage of the development process by;

- using the window of opportunity to explore or implement certain features or techniques;
- making the right decisions at the right time;
- ensuring that decisions are made as part of an integrated programme; and
- avoiding the early foreclosure of decisions but not delaying the decision-making process any longer than necessary.

56. Periodic review of the HPC environment case has taken into account a process via which BAT is demonstrated on the HPC project which have a direct impact on the Environment Case presented for SZC. These are illustrated in Figure 3-2 below:

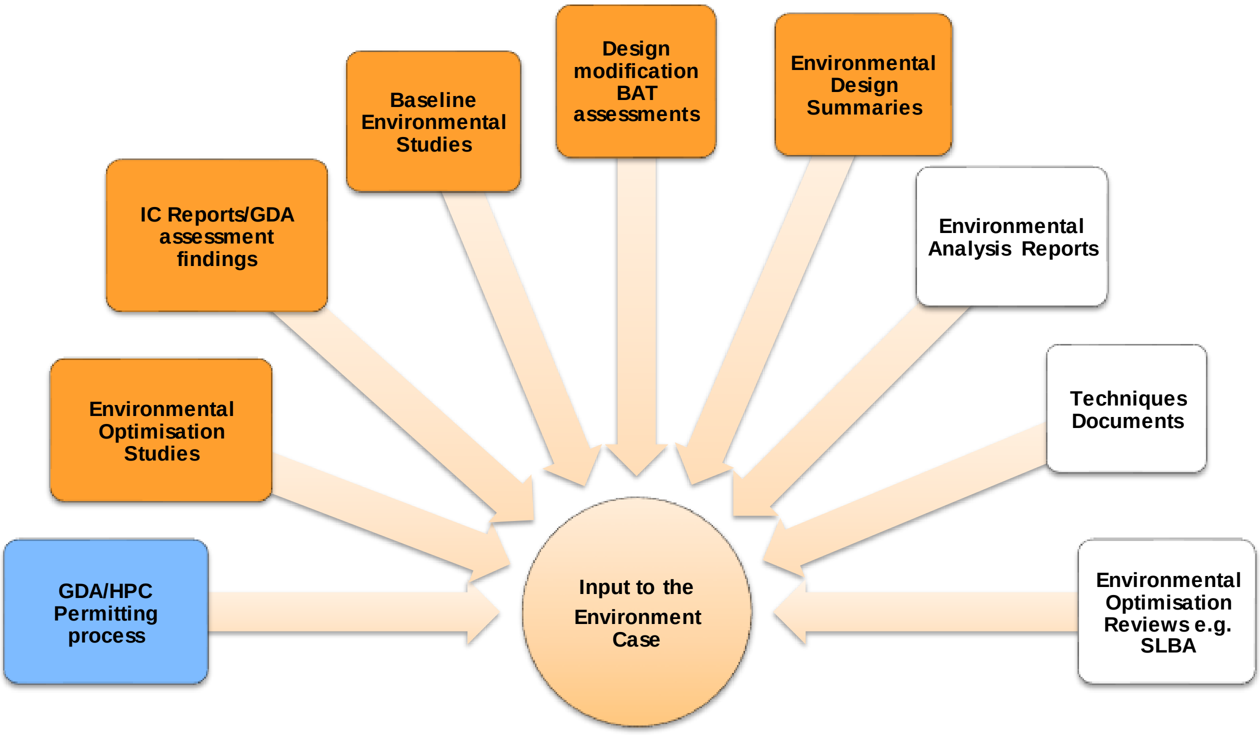

Figure 3-2 Inputs into the Environment Case

57. Figure 3-2 shows in blue the baseline information presented in the environment case at the application stage, and in orange, key project deliverables or processes that have contributed to the ongoing development of the Environment Case BAT demonstration, and been incorporated via periodic review. In white it shows future deliverables that have been identified as contributing to the Environment Case, but have not been produced

yet given the current state of the project. The list of identified future deliverables is based on known identified work, and is not necessarily exhaustive.

58. The deliverables identified in orange which contribute to the demonstration of BAT for the baseline SZC design are summarised below:

- **Environmental Optimisation Studies (EOS) –** a number of EOS/BAT assessments have been produced to contribute to the detailed design of HPC, and address open points that were identified during the GDA and during the HPC permitting process. Often EOS studies contribute to closure of permit information conditions, or GDA assessments findings, which are covered below, however this is not always the case. These studies have been undertaken to address areas where further detailed BAT analysis is required as part of detailed design, to build upon the Environment Case that was demonstrated at GDA and in the HPC permit application. As such there is not a clear link between the EOS studies produced and the individual claims in the environment case, rather they have been produced to address specific issues. There are not expected to be any new EOS identified and undertaken specifically for SZC.
- **Information Condition Reports/GDA Findings (GDAF) closures –** At the GDA stage for the UK EPR^{TM}, the Environment Agency raised a number of assessment findings that would require NNB GenCo (HPC) to produce further work to address. Following the HPC permit application stage, a number of these assessment findings were also formalised into information conditions issued with the permit. Further detail on the status of these with regards to the SZC project is presented in section 3.3. Following closure of the relevant GDAF/Information condition by the Environment Agency, the report would be integrated into the environment case at the next periodic review.
- **Baseline Environmental Summaries (BES) –** For new systems in the HPC design, that were created as the result of detailed design, design change or otherwise not presented at GDA, NNB GenCo (HPC) process requires the production of a BES to set the Baseline Environment Case of the system that would otherwise have been presented at GDA. This identifies the need to identify BAT at an early stage of the design process when options are being conceived, evaluated and decided on.
- **Design change BAT assessments –** The HPC project has a process for management of changes to the design, which requires changes to be assessed for environmental significance, and if necessary a BAT assessment to be produced to ensure that BAT has been considered in the optioneering assessment process, and that the final design change represents BAT.
- Since the HPC permit application, the HPC design has matured through two design configurations (RC1.2 and RC2) which have frozen the design documentation and formally incorporated accepted design changes. Where BAT assessments have been produced to accompany design changes at both RC1.2, and RC2, they have been formally reviewed & accepted by NNB GenCo (HPC), and then incorporated into periodic updates for the HPC Environment Case (which are aligned to the RC). This HPC Environment Case was the starting point for the SZC Environment Case, as described above.
- Further detail regarding the review and acceptance of design changes into SZC is provided in section 3.2.3. Given that the SZC RC0 design is consistent with HPC RC2, all design changes currently incorporated into RC0 for SZC, were initiated by the HPC project. It should be noted that for future design changes originating from the HPC and SZC project, SZC Co. will review and accept, as appropriate design changes according to the design change process. This step ensures that the SZC IC is involved in the design change process and responsible for ensuring any design development accepted into the SZC design is appropriate and represents BAT, including implementation of the replication strategy as far as reasonably practicable. As described in the management

arrangements section and FWP of the RSR Permit Application Head Document [Ref 1], SZC will review, adopt and implement, as appropriate, the HPC design change process.

- **Environmental Design Summaries (EDS) –** Where manufacturers are responsible for the design of systems, structures or components with environmental significance, the contractor is required to produce an EDS deliverable, which demonstrates that BAT has been applied and the design has been optimised with regards to the environment. Where significant to the claims-arguments-evidence in the environment case, these EDS's will be identified references. Generally speaking, given that contracts/contractors may not be replicated between the HPC and SZC projects, EDS's produced to support the HPC project will not be incorporated into the SZC Environment Case, though there may be exceptions to this in future if consistency is established in the supply chain between both projects.

59. Unless it is stated above that the deliverables are subject to a specific process, the deliverables identified above would be subject to the 'Review & Accept project deliverables' procedure, the existing HPC procedure will be reviewed and adopted into SZC Co. as appropriate according to the management arrangements section of the RSR permit application Head Document [Ref 1]. This is applicable to internal NNB GenCo (HPC) and SZC Co. deliverables, deliverables from the Responsible Designer (RD) and external contractor deliverables.

3.2.1 Environmental Optimisation Studies

60. EOS studies have been produced which cover a number of topic areas including (but not limited to):

- Discharge/in-process monitoring arrangements.
- Options assessments for solid waste streams.
- Justification of demineralisation media and filter porosity.
- Discharge tanks valve configuration.
- Minimisation of particulate matter in discharges.
- Minimisation of the use of Stellites in the primary circuit.
- High Efficiency Particulate Air (HEPA) filter and iodine trap efficiency testing.

61. Where appropriate these EOS are identified references in the current HPC environment case, and have been determined as relevant to the SZC design, and so are also identified references supporting the SZC Environment Case (Section 6 of this document). Studies may have been produced by NNB GenCo (HPC), the RD, or other third party contractors. The process for review and acceptance of these deliverables is summarised in section 3.4.

3.2.2 Baseline Environmental Summaries

62. **Table *3-1*** below sets out Baseline Environmental Summaries which have been referenced in the environment case, and references to the relevant CAE where they are incorporated:

Table 3-1 Baseline Environment Summaries and CAE grouped by system

System	Baseline Environmental Summaries Description	Relevant CAE
Baseline Environmental Summary for HXA, HVD and HVL	The Liquid Radwaste Monitoring and Discharge System (9KER), Additional Liquid Waste Discharge System (9TER), Site Liquid Waste Discharge System (9SEK) and Fuel Pool Cooling System (9PTR), tank building (HXA), Hot Workshop, Hot Warehouse, Facilities for Decontamination Building (HVD) and Hot Laundry Building (HVL) are all new buildings that were not present in GDA.	Evidence 182 – 6.5.2.1.1 Evidence 186 – 6.5.2.1.1 Evidence 189 – 6.5.2.1.4
Baseline Environmental Summary for the optimisation of the Site Laundry and Hot Decontamination System (9SBE)	The 9SBE consists of two main parts; the active laundry located in HVL and the hot decontamination workshop located in HVD. The current strategy for the SZC project does not include an active laundry on site, however the discharge system is designed to take effluent from the laundry if the operator chooses to fit one. The BES considers the potential environmental impact of any potential laundry system.	Evidence 98 – 6.2.4.4.2 Evidence 193 – 6.5.2.2.1
Baseline Environmental Summary for 2/9RPE	The Effluent Treatment Building Nuclear Vent and Drainage System (2RPE) and Site Nuclear Vent and Drainage System (9RPE) are new systems that were not present in GDA, given that HXA, HVD, HVL & Extension of Nuclear Auxiliary Building for Unit 2 (HQC) are all new buildings for HPC.	Evidence 23 – 6.1.4.6 Evidence 48 – 6.2.1.2.1 Evidence 193 – 6.5.2.2.1
Baseline Environmental Summary for 9PTR system	The 9PTR system (an additional means of storing and transferring borated water) is a modification to the existing EPR design. It is an extension to the PTR purification system on both HPC units 1 and 2. The system has the role to store and transfer volumes of borated water between the In-Containment Refuelling Water Storage Tank (IRWST) and HR pool of both units and the 9PTR tanks. In accordance with the current FA3 & HPC safety requirements, this allows the transition from plant state D to plant state E during unit outages and also allows parallel inspections and maintenance of IRWST and HR pools (during 10 yearly inspection refuelling outage).	Evidence 51 – 6.2.1.2.4 Evidence 193 – 6.5.2.2.1

3.2.3 Review of design developments made since the HPC RSR Permit application

63. The approach taken by SZC Co. utilises a replication strategy for the UK EPR^{TM} series design (see Section 2.4); to ensure that as far as is reasonably practicable the SZC design remains consistent with that for HPC, provided that this continues to represent BAT. Section 3.3 outlines site specific considerations that have been assessed to ensure that this is appropriate. As far as is practical the design of SZC will replicate that of HPC. A consistent state of design is referred to as a reference configuration, the most recent of which for HPC is RC2.

64. A large number of design changes have arisen since GDA established the basic design. In order to ensure suitably controlled design development, and to demonstrate that the reference configuration continues to

represent BAT, it is necessary to assess the design changes for environmental significance and where necessary produce a suitable and proportionate assessment to determine that the design change represents BAT.

From an Environmental perspective design changes are initially reviewed against a number of screening questions to determine if further assessment is required. Design changes are then ranked using a scoring system based on 3 criteria:

- Environmental Impact – Definition similar to that of Environmental Impact Assessments, ranging from permanent widespread irreversible damage, to temporary minor effect on the environment.
- Formal Requirements – Effect of the modification on ability to comply with Permit conditions, discharge limits, or would require a variation to one/more environmental permit.
- Standardisation – Modification that would differ from existing UK standards/practices, Flamanville 3 or other EPR^{TM}'s, or existing practices in EDF international fleet.

65. Design changes are then assigned one of the following ranks:

- N - A modification that could not affect the environment, even if inadequately conceived or implemented (ICOI). A modification is ranked N if all screening questions are answered no.
- E4 – Modification that could affect the environment if ICOI, but could only have negligible impact on the environment or against formal requirements.
- E3 - A modification affecting the environment that could not result in a significant impact even if ICOI
- E2 - A modification affecting the environment that could result in a significant but not serious impact, including against regulatory requirements, if ICOI
- E1 - A modification affecting the environment which results in a significant alteration to a fundamental environmental principle, or requires a significant variation to an environmental permit or will require a new major environmental permit, or that could result in a serious pollution incident if ICOI.

66. For E4/N's no further BAT assessment is required. For E4 modifications good engineering process will be applied and this is considered sufficient to ensure any environmental impact is minimal and minimised. For E3 and above the BAT assessment produced is proportionate to the ranking and the risk involved, with an E3 usually requiring a proforma to be completed, whereas for E1 a full bespoke BAT assessment would be expected.

67. As described earlier, to maintain consistency between HPC & SZC, the initial reference configuration for the SZC project is based on RC2 for HPC. In order to formalise each reference configuration into the consistent state from an environment perspective, typically an advice note is produced to summarise the changes with respect to the environment. Advice notes have been issued covering the design from the HPC permit application up to RC1.0 [Ref 17], and then for subsequent design freeze RC1.2 [Ref 18]. An advice note is currently being produced by the HPC project to summarise RC2, however, at the point of SZC RSR permit application this is yet to be issued.

68. As the RC2 design is now frozen, the process for demonstrating BAT for SZC includes demonstrating that RC2 design changes have been suitably assessed and; where required, a suitable BAT justification has been incorporated/referenced.

69. The HPC design change procedures require environmental input to, and assessment of, each change to the design of the facility. This ensures BAT is considered throughout the SZC design. Similar arrangements to be

implemented on the SZC project are detailed in the RSR permit application Support Document E3 (RSR Compliance Matrix) [Ref 14].

3.2.4 Permit Information Conditions

70. As stated earlier in section 3.2, a number of HPC information conditions, and GDA assessment findings were raised by the Environment Agency for NNB GenCo (HPC) to address. A comprehensive list of these HPC information conditions and GDA findings, their current status and their relationship with the SZC permit application are presented in the permit application head document.

71. The HPC information conditions which have been addressed and resulted in updates to the environment case are summarised in the table below, along with the reference to the Claims-Argument-Evidence where they are referenced (the RSR application Head Document provides a full list of the HPC information conditions, beyond the direct environment case link):

Table 3-2 Summary of HPC permit Information Conditions aligned to relevant CAE

IC	Description	Status	Relevant Claims/Arguments
IC 4	The operator shall provide the Environment Agency with a report that demonstrates that requirements for the sampling of discharges have been adequately considered in the design of the plant. Matters to be considered include sufficient space for equipment, suitable sampling arrangements, suitable and safe access, and suitable environmental conditions.	The Final report to close out HPC IC4 was submitted to the Environment Agency in December 2018. The report is concerned with the design of monitoring/sampling arrangements for discharges (but not the discharge outlets themselves) so therefore the contents of the report are considered applicable to SZC, and have been incorporated into the environment case, providing evidence to demonstrate that the design of monitoring/sampling arrangements for liquid/gaseous discharges is BAT.	**Claim 5, Argument 24, Sub-Argument 28** – Sampling and monitoring of radioactive gaseous discharges **Claim 5, Argument 25, Sub-Argument 30** - Sampling and monitoring of radioactive aqueous discharges
IC 8	The operator shall provide the Environment Agency with a report on the use of BAT to minimise the production of activated corrosion products. The report shall consider the possible improvements identified in the Pre-Construction Environmental Report: the corrosion resistance of steam generator tubes, the electro-polishing of steam generator channel heads, the specification of lower cobalt content reactor system construction materials and the use of Stellites in reactor components, in particular the coolant pumps.	Final submission of the report took place in Q2 2018. The report demonstrates that the specification of low cobalt content materials, and reduction of stellite usage in the primary circuit. The specification of materials in the primary circuit is not a site-specific concern so the report is considered applicable to SZC.	**Claim 1, Argument 4** – Specification of Materials

IC	Description	Status	Relevant Claims/Arguments
IC 9	The operator shall provide the Environment Agency with a report on the detailed design proposals for the Liquid Waste Processing System including a BAT assessment.	Final report to close out HPC IC9 was submitted in December 2018. The report, along with the associated HPC IC10 report, and planned work to close out HPC IC11, resulted in new arguments and evidence being created to support the BAT demonstration of TEU. The discharge routes or other site specific elements are not contained within the TEU so the work is considered applicable for SZC.	**Claim 2 Argument 11** – Capacity and resilience of the liquid waste processing system (TEU) **Claim 2 Argument 12** – Minimisation by the management and abatement of radioactive aqueous effluents
IC 10	The operator shall provide the Environment Agency with a BAT assessment to show that the use of the evaporator, the choice of filter porosity and the demineralisation media has been optimised. The operator shall also provide evidence that the Liquid Waste Processing system has sufficient capacity and resilience (for example, in case of outage due to maintenance or breakdown) to cope with all the aqueous radioactive waste arisings.	Final report to close out HPC IC10 was submitted in December 2018. The report, along with the associated HPC IC9 report, and planned work to close out HPC IC11, resulted in new arguments and evidence being created to support the BAT demonstration of TEU. The discharge routes or other site specific elements are not contained within the TEU so the work is considered applicable for SZC .	**Claim 2 Argument 11** – Capacity and resilience of the TEU **Claim 2 Argument 12** – Minimisation by the management and abatement of radioactive aqueous effluents

3.3 SZC Environment Case Management

3.3.1 SZC Environment Case Development

72. In order to successfully adapt the HPC Environment Case to SZC, it is necessary to consider aspects of the HPC Environment Case that may not be applicable to SZC. The replication strategy between the HPC and SZC designs is intended to ensure that the design of the SZC nuclear island will be identical to that for HPC, and therefore radioactive waste generation will also be the same, however it is necessary to ensure that assumptions which have been justified for HPC, are equally justifiable for SZC.

73. As such it is necessary to consider local conditions around the SZC site, and how these conditions will affect the impact of SZC on the local environment. The replication strategy is intended to ensure that the source term associated with the nuclear island of SZC is identical to that of HPC, however the pathways and receptors are unique to the local environment.

74. A detailed line-by-line assessment of the Environment Case for applicability to SZC has not been undertaken, however in adapting the Environment Case for SZC, SZC Co. is required to act as IC, ensuring suitably qualified and experienced personnel have considered the potential site specific aspects which have had to be re-assessed for SZC in order to confirm that assumptions made regarding HPC continue to be correct, or that further design change may need to be considered.

75. These site specific aspects are summarised in the table below:

Table 3-3 Sizewell C Site Specific design aspects

Site specific Issue	Description	Relevant CAE
Stack Height	A report has been produced to consider the optimal stack height for SZC. The assessment considered a number of site specific factors including the variation of dose impact associated with changes in height, and the visual impact on the local landscape. The optimal stack height was established to be 70m for the SZC reference design (which is the same as that specified for the HPC RC2 reference design).	Claim 4, Argument 22, Evidence 156
Outfall tunnel	The heat sink part of the cooling water pumping stations and marine work infrastructure, which due to site specific nature requires some redesign from HPC, there is no impact to the NI. This changes the altimetry of the buildings (i.e. sizes, heights, etc) to accommodate the different tidal range. There is no change to the functionality, operation or faults/hazards.	Claim 4, Argument 21, Sub-argument 25, Evidence 151
Interim Spent Fuel Store (HHK) and Intermediate Level Waste (ILW) Interim Storage Facility (HHI)	Due to the different site layout and available space at SZC, the shape of the HHK and HHI buildings have been modified on the SZC plot plan. This does not change the function of the structures, systems or components.	Claim 2, Argument 9, Sub-Argument 5, Evidence 61

76. It is also noted that the radiological impact assessments are site specific. Dose assessments have been produced to accompany the SZC RSR permit application and support the evidence presented in this document. These consist of a human and non-human biota assessment presented in supporting documents D1 and D2, [Ref 10] and [Ref 19], respectively. These consider the site specific pathways and receptors via which SZC will impact the environment, and consider habits of the local population. Where appropriate within this document, the specific results from these assessments are quoted.

3.3.2 Ongoing Demonstration of BAT Throughout the Lifecycle of the Installation

77. Beyond the demonstration of BAT at the current stage of development of the installation it is necessary to continue to do so throughout the lifecycle of the installation. The Environment Case continues to be subject to periodic review according to key project milestones, and design RCs. These reviews incorporate any new BAT related deliverables (as set out in Section 3.2) that have been produced in the intervening time that support the SZC Environment Case. As the stage of development moves forward from design to construction, commissioning and operation there will be increasing emphasis on the application of the selected management options in terms of detailed design, management, operation and maintenance issues.

78. The methodology set out for the demonstration of BAT is considered to be complementary to the approach to the development of a robust safety case and to be consistent with the overall objective of development of an integrated management system to achieve the protection of workers, the public and the environment. It is incorporated into the integrated management system for the purpose of ongoing BAT demonstration through the lifecycle of the installation. Further details on the arrangements in place to support the production of future BAT related deliverables are covered in the head document.

79. [SZC RSR CMT1] of the Forward Work plan set out in the SZC Permit Application head document [Ref 1] sets out how SZC Co. will ensure that organisational learning is successfully implemented on the SZC project.

80. Additional BAT requirements imply that, in order to obtain the authorisations to discharge radioactive substances in the UK, the operators shall keep abreast of new abatement and treatment technologies. This is in particular to improve the transparency of the decision making process. It is believed that the techniques

currently envisaged for the treatment of effluents discharged from the EPR™ are the best available at the current time, although it is expected that they will be periodically reassessed and potentially replaced or added to by the more advanced techniques currently under development in the future.

81. This is consistent with the BAT approach at HPC requiring ongoing optimisation and assessment of the treatment techniques in use, and consideration that BAT for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding and commercial availability. This also includes the consideration of the replication strategy and assumed benefit of Next of a Kind development.

3.3.3 Open Point management

82. As discussed above, forward actions of future planned BAT assessments identified within the Environment Case will be captured and managed via the open point register, this register currently sits within NNB GenCo (HPC), however, there is provision made for including SZC Open Points and sharing the information [Ref 16] . Open points may either require SZC Co. to perform a specific action, or to confirm that an action has been performed by another stakeholder, however the onus of responsibility is on SZC Co. for the closure of the open point. For HPC owned open points, SZC Co. will review and adopt the closure as applicable, this will be captured formally within the SZC Co. arrangements for open points, see RSR application Head Document [Ref 1]. The register is currently a shared arrangement between HPC and SZC, given that certain open points are applicable to both projects.

83. Once an open point is identified, a description is recorded of the action required and associated risks/impacts. Each open point is then assigned a qualitative rating of the associated risk according to the following criteria:

- Low risk - The outcome of the open point will not impact the findings of the original report and/or will not result in any environmental impact. Where not raised through a BAT report, this is where the impact of the open point on the design of the equipment, input into procurement specifications or construction is considered insignificant and will not significantly impact the final design of Key Environmental Protection Equipment (KEPE).
- Med Risk - The outcome of the open point may impact the BAT outcome of the report or may have some (but not significant) environmental impact. Where not raised through a BAT report, this is where the impact of the open point on the design of the equipment, input into procurement specifications or construction may be considered significant and/or could significantly impact the final design of KEPE.
- High Risk - The outcome of the open point could significantly challenge the findings of the BAT report or result in significant environmental impact. Where not raised through a BAT report, this is where the impact of the open point on the design of the equipment, input into procurement specifications or construction is considered significant and/or would significantly impact the final design of KEPE.

84. Each open point is then assigned a lead who is responsible for management and closure of the open point, and capture comments to cover actions planned to resolve or review of the open point. A need date is also captured on the register, related to a relevant project milestone, such as the signature of a key contract, or design freeze. A rating of open/planned closed is assigned according to the following criteria:

- Open: Topic under review to develop plan/action to resolve
- Planned: Action/Activity currently planned to close out open point.
- Closed: Action/Activity completed, or is considered part of normal business and does not require

further tracking through this register

85. Periodic review meetings are undertaken to confirm the closure of open points, and review the status/progress of all high, open, or new open points. Open points are closed either when the required action is completed, or when it is confirmed to be closed out by another process (e.g. information conditions, or once a design change has been created for instance). The open point register [Ref 16] also includes a list of completed and proposed future BAT assessments or related deliverables ([SZC RSR CMT3] in the FWP in the SZC RSR Permit Application Head Document [Ref 1].

4 Environmental Protection Function

4.1 Overview of the Environmental Protection Function Register

86. Environmental legislation (Environmental Protection Act 1990 and Environment Act 1995) places an inherent requirement on SZC Co. to prevent uncontrolled, increased, or potentially harmful discharges to the environment, by ensuring equipment that provides an environmental protection function (EPF) is correctly operated and maintained.

87. Furthermore, the standard, generic RSR Environmental Permit conditions specified by the Environment Agency [Ref 20], and therefore in any prospective RSR environmental permit granted to SZC Co. under the Environmental Permitting (England and Wales) Regulations 2016 (as amended), include a number of conditions related to equipment providing an EPF. For example, condition 2.3.4 of the RSR permit states:

> *“The operator shall maintain in good repair the systems and equipment provided:*
>
> *(a) to meet the requirements of conditions 2.3.1, 2.3.2 and 2.3.3 [these are the general requirements to apply Best Available Techniques (BAT) to minimise waste, minimise effluents and minimise environmental impacts];*
>
> *(b) to carry out any monitoring and measurements necessary to determine compliance with the conditions of this permit;*
>
> *(c) to measure and assess the exposure of members of the public and radioactive contamination of the environment.”*

88. At the GDA stage, EDF and AREVA (now Framatome), as the requesting party, presented a methodology to classify and categorise safety functions to fit the UK requirement which was accepted by Office for Nuclear Regulation (ONR). In response, the Environment Agency stipulated the following assessment finding (UKEPR-AF21) arising from the GDA process.

> *“Future operators shall provide evidence during the detailed design phase that the methodology (developed in response to GDA Issue GI-UKEPR-CC-01) used for categorising safety function and classifying structures, systems and components (SSCs) has been applied to relevant SSCs that deliver an environmental protection function.”*

89. To address this assessment finding, NNB GenCo (HPC) developed the EPF Register. The EPF Register is a live database of environmentally significant equipment and information relating to its function(s), requirements and other relevant information. The register demonstrates that equipment important for RSR permit compliance for HPC, as well as for other operational environmental permits (it is therefore not limited to equipment related to radioactive substances). The EPF Matrix also serves as a reference for information such

as environmental permit relevance, environmental risk and design and operational requirements as shown in Section 4.1.

90. An EPF is defined as a function provided by a system, structure or component that provides protection to the environment. By design the EPF functions are intended to relate to the claims made in the Environment Case, though there is not always a simple one-to-one relationship. The relationships are identified in the summary table below. The recognised functions are Minimisation, Containment, Abatement, Treatment, Mitigation, Monitoring and Optimisation as defined below:

Table 4-1 Cross Referencing between Environmental Protection Function and Claims

Environmental Protection Function	Description	Related Claims
Minimisation	Minimisation of waste generation at source e.g. by de-oxygenating water, corrosion is limited which minimises build-up of corrosion products.	Claim 1
Containment	Including storage, transfer and leaktightness of radioactive or hazardous materials or effluent e.g. containing liquid radioactive/hazardous waste in a tank.	Claim 2
Abatement	Abatement of effluents from routine operations to minimise discharges e.g. use of demineraliser to remove soluble radioactivity from aqueous effluent prior to discharge; or use of HEPA filters to remove particulate radioactivity from a gaseous effluent waste stream prior to discharge.	Claim 2
Treatment	Treatment of solid waste from routine operations to minimise the volume of waste disposed of off-site e.g. compaction or shredding of solid waste to reduce volume.	Claim 3
Mitigation	Mitigation of waste arising from unplanned and accidental events and controls to prevent unauthorised discharged or non-compliant waste disposal e.g. bunds around chemical storage tanks.	Function is exclusively applied to non-RSR related equipment4
Monitoring	Monitoring and control including in-process and discharge monitoring and relevant Instrumentation & Control (I&C) to ensure compliance with the relevant conditions of the permits/consents etc. e.g. flow measurement to ensure that discharges are within the permitted volumes.	Claim 5
Optimisation	Optimisation of equipment, primarily associated with solid radioactive waste management, where it assists in the sorting and segregation of waste streams so as to make best use of the available disposal routes. In this respect it may minimise secondary waste arisings by avoiding the unnecessary creation of radioactive waste; however, it differs from the "minimisation" function because it does not minimise the source term of radioactivity or generation of waste at source. Optimisation may also include the preferential partitioning of radionuclides between media. e.g. a valve to transfer resin to waste treatment systems for further treatment; once sentenced resins cannot be recovered.	Claim 2, Claim 3 & Claim 4

91. The functions that have been identified clearly link to the high-level claims around which the SZC Environment Case is constructed, though this relationship is not one-to-one, and the flexibility of the functions identified allows them to be applied in non-rad areas as well.

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[4] Mitigation of radioactive faults is covered by the Nuclear Safety Case regulated by ONR.

92. Equipment assessed was assigned one of the following designations:

- **Environmental Protection Equipment (EPE)** – Equipment identified that provides an EPF (i.e. one or more of those identified in the table above).
- **Key Environmental Protection Equipment -** KEPE is the most important EPE identified and prioritised as part of the risk assessment process.
- **No Environmental Protection Requirement** - Equipment that does not contribute to delivering an EPF.

93. A risk assessment is undertaken for equipment for which an EPF function is identified, to determine EPE/KEPE status. This risk assessment quantitatively assesses consequences and environmental impact of failure of the equipment to assess overall severity of failure. Engineering judgement is then applied for the final determination of EPE/KEPE.

4.2 Relationship with the SZC Environment Case

94. The EPF register was developed after the HPC RSR permit application was submitted and is now a key arrangement for RSR permit compliance at HPC, along with the Environment Case. Given it is aligned to the HPC reference design, any design requirements denoted within are also of relevance to SZC and as such it is considered a key source of information for the SZC project.

95. The EPF register currently reflects HPC RC1.2, with work planned to update it according to RC2. The current register, at RC1.2, is considered common between the HPC & SZC projects, however it is setup in a way to support the replication strategy and also the divergence of the HPC and SZC projects, if required in the future. As part of the first reference configuration update for SZC (RC1), the existing register will be updated on a SZC specific basis with the intention that a separate register is maintained for each project, which reflects site specifics. The forward work to do this is covered under [SZC RSR CMT2] of the forward work plan [Ref 1].

96. The Environment Case set out in section 6 addresses at a high level, via reasoned logical argument, the overall Environment Case for SZC, and identifies the underpinning references upon which that Environment Case is reliant. The EPF register signposts to design requirements relevant to BAT for each particular equipment, and identifies follow-on requirements for installation, commissioning and operations. Between the environment case, and the EPF register it is ensured that BAT is considered at both the holistic high level, right down to for particular systems, structures and components.

97. It should be noted that no information relevant to BAT is primarily captured in the EPF register, rather it signposts towards the assessments or arrangements which include the BAT justification or assessment. The assessments or arrangements referenced would also serve as identified references within the environment case. It is important in ensuring that the BAT claims identified in the environment case are filtered down to the equipment level, and that suitable follow-on requirements are identified to ensure BAT is continually applied throughout the project lifecycle.

5 Summarising the Environment Case for SZC

5.1 Application of BAT to Key Radionuclides

98. **Table *5-1*** below summarises for each radionuclide how minimisation at source is achieved and which techniques are applied to abate discharges. It is through the use of abatement techniques that the activity discharged and the associated impacts are minimised.

Table 5-1 Techniques for minimisation of waste at source grouped by radionuclide

Radionuclide/ Group of radionuclides	Minimisation at source	Abatement in liquid discharges	Abatement in gaseous discharges
Tritium	Enrichment of boron to increase levels of boron-10 in the injected boric acid. Depletion of lithium-6 in the injected lithium. Optimal pH control by boron-lithium coordination. Use of gadolinium oxide as a burnable poison. Optimisation of the gadolinium load. Use of control rods without boron. Use of secondary neutron sources with lower mass of beryllium. High standards of fuel design and fabrication. Improved management of Coolant Storage and Treatment System (TEP) based on N4 PWR.	None available.	None available.
Carbon-14	Improvement of core design (compared to existing PWRs). Management of nitrogen concentration in primary coolant.	None Available (though a small proportion may be abated inadvertently via filtration & deminerlisation)	None available.
Noble Gases	High standards of fuel design and fabrication to minimise fuel cladding defects and residual traces of uranium on the surface of the fuel; Improvement of fuel performance. Reactor operation to minimise the risk of fuel failure and control the concentration of fission products in the primary coolant. Identification and removal of leaking fuel pins during refuelling. The techniques listed above also apply to any other fission products.	TEP Degasser	Charcoal delay beds; Recycling of the purge gas in the TEG;
Isotopes of Iodine	See noble gases above.	Filtration; Demineralisation (ion exchange resins); Recirculation of effluents in the demineralisers of the TEU; Use of delay and monitoring tanks.	Charcoal delay beds; Recycling of the purge gas in the TEG; Iodine traps (filtration).
Cobalt-58 and Cobalt-60	Use of cobalt-free material as an alternative to Stellite™. Minimisation of cobalt-content of materials where required. Use of 690 alloy for steam generator tubes. Hot functional tests during plant commissioning. Optimisation of the primary circuit chemistry. Use of helicoflex seals and avoidance of antimony in bearings Use of zinc injection.	Filtration; Demineralisation (ion exchange resins); Evaporation.	HEPAfiltration.

Radionuclide/ Group of radionuclides	Minimisation at source	Abatement in liquid discharges	Abatement in gaseous discharges
Cs-137	Use of quality assured fuel manufacturing arrangements to minimise the quantities of residual traces of uranium present at the surface of the fuel. Cladding to minimise fuel leakage.	Filtration; Demineralisation (ion exchange resins); Recirculation of effluents in the demineralisers of the TEU.	
Others	Specification of materials. Hot functional tests during plant commissioning. Optimisation of the primary circuit chemistry.	Filtration; Demineralisation (ion exchange resins); Evaporation	HEPA filtration

5.2 Application of BAT to Key Systems

99. Building on the identified systems described in the SZC RSR Permit Application Head Document [Ref 1], Table 5-2 presents the systems having been aligned to the various relevant claims and arguments presented in Section 6.

Table 5-2 BAT claims and argument grouped by system

System	Relevant claims and arguments[5]
Reactor Coolant System (RCP)	C1A4 - Specification of Materials C1A5 - Management of Primary Coolant Chemistry to Minimise the Activity and Generation of Radioactive Waste C1A6 - Commissioning, Start-up and Shutdown procedures C2A9 - Design, Construction and Operation of Containment Systems C2A10SA2 – Design to prevent / minimise discharges during decommissioning C2A12SA15 - Ion Exchange of Liquid Effluents (for demineralisers in the Nuclear Steam Supply System (NSSS)) C2A12SA16 - Selection of Ion Exchange Resins (for demineralisers in the NSSS) C3A16 - Design to minimise the volume of operational and decommissioning waste arisings
Chemical and Volume Control System (RCV)	C1A5 - Management of Primary Coolant Chemistry to Minimise the Activity and Generation of Radioactive Waste C2A9 - Design, Construction and Operation of Containment Systems C2A10SA7 - Reactor Start-up and shutdown procedures C2A12SA15 - Ion Exchange of Liquid Effluents C2A12SA16 - Selection of Ion Exchange Resins C2A12SA18 - Filtration of Liquid Discharges C2A13SA22 - Decay Storage of Gases prior to Discharge C4A20- Preferential Partitioning of Radionuclides
Nuclear Island Sampling system (REN/RES)	C1A5 – Management of Primary Coolant Chemistry to Minimise the Activity and Generation of Radioactive Waste C2A10SA6 - Control of Coolant Chemistry to Ensure Integrity of the Secondary Circuit C2A10SA7 - Reactor Start-Up and Shutdown Philosophies C2A12SA15 - Ion Exchange of Liquid Effluents C2A12SA19 - Segregation and Management of Liquid Effluents
Steam Generator Blowdown System (APG)	C2A10SA6 - Control of Coolant Chemistry to Ensure Integrity of the Secondary Circuit C2A12SA15 - Ion Exchange of Liquid Effluents C2A12SA18 - Filtration of Liquid Discharges C2A12SA19 - Segregation and Management of Liquid Effluents
Nuclear Vent and Drain System	C1A4 - Specification of Materials C2A9 - Design, Construction and Operation of Containment Systems C2A12SA19 - Segregation and Management of Liquid Effluents C2A12SA20 - Decay Storage of Liquid Effluent prior to Discharge

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[5] Nomenclature for claims and arguments is as follows: CxAxSAx where x denotes the number of the C (Claim), A (Argument) or SA (Sub Argument). For example, C2A13SA24 relates to Sub Argument 24 of Argument 13 in Claim 2 of the SZC Environment Case (as detailed in Section 6).

System	Relevant claims and arguments[5]
Coolant Storage and Treatment System	C2A9- The Design, Construction and Operation of Containment Systems C1A5 - Management of Primary Coolant Chemistry to Minimise the Activity and Generation of Radioactive Waste C2A12SA15 - Ion Exchange of Liquid Effluents C2A12SA17 - Evaporation of liquid discharges C2A12SA18 - Filtration of liquid discharges C2A12SA19 - Segregation and Management of Liquid Effluents C2A12SA20 - Decay Storage of Effluent prior to discharge C3A17 - Selection of Methods to Minimise Solid Waste Generation C4A20 - Preferential Partitioning of Radionuclides
Reactor Boron Water Make-up System (REA)	C1A5 - Management of Primary Coolant Chemistry to Minimise the Activity and Generation of Radioactive Waste C2A12SA15 - Ion Exchange of Liquid Effluents
Spent fuel pool water cooling system and fuel pool water processing system	C2A9 - The Design, Construction and Operation of Containment Systems C2A10SA8 - Design to prevent/minimise discharges during decommissioning C2A12SA15 - Ion Exchange of Liquid Effluents C2A12SA16 - Selection of Ion Exchange Resins C2A12SA17 - Evaporation of liquid discharges C2A12SA18 - Filtration of liquid discharges C4A20- Preferential Partitioning of Radionuclides
In-Containment Refuelling Water Storage Tank (IRWST)	C2A9 - The Design, Construction and Operation of Containment Systems C2A10SA8 - Design to prevent/minimise discharges during decommissioning C4A20- Preferential Partitioning of Radionuclides
Gaseous Waste Processing System (TEG)	C2A9 - The Design, Construction and Operation of Containment Systems C2A10SA8 - Design to prevent/minimise discharges during decommissioning C2A10SA7 - Reactor Start-up and Shutdown procedures C2A13SA22 – solid radioactive C2A13SA23 - Process Gas Recirculation System C2A13SA24 - Filtration of gaseous discharges C4A20 - Preferential partitioning of radionuclides
Solid Waste Treatment System (TES)	C2A10SA8 - Design to prevent/minimise discharges during decommissioning C2A12SA17 - Evaporation of Liquid Discharges C2A15 - Decay Storage of Solid Radioactive Waste C3A17 - Selection of Methods to minimise solid waste generation C3A18 - Application of Volume Reduction Processes to Solid Wastes
Liquid Waste Processing System	C1A6 - Commissioning, Start-Up and Shutdown Procedures C2A9 - The Design, Construction and Operation of Containment Systems C2A12SA15 - Ion Exchange of Liquid Effluents C2A12SA16 - Selection of Ion Exchange Resins C2A12SA17 - Evaporation of liquid discharges C2A12SA18 - Filtration of liquid discharges C2A12SA19 - Segregation and Management of Liquid Effluents C2A12SA20 - Decay Storage of Effluent prior to discharge C4A20 - Preferential partitioning of radionuclides C4A21 - An appropriately designed Liquid Effluent Discharge System will minimise impacts of discharges to the environment

System	Relevant claims and arguments[5]
Condenser Vacuum (CVI)	C2A13SA23 - Process Gas Recirculation System C2A13SA24 - Filtration of Gaseous Discharges
Liquid Radwaste Monitoring and Discharge System	C2A9 - The Design, Construction and Operation of Containment Systems C2A12SA17 - Evaporation of liquid discharges C4A21 - An appropriately designed Liquid Effluent Discharge System will minimise impacts of discharges to the environment
Additional Liquid Waste Discharge System (TER)	C2A12SA18 - Filtration of liquid discharges C4A21 - An appropriately designed Liquid Effluent Discharge System will minimise impacts of discharges to the environment C4A20- Preferential partitioning of radionuclides
Site Liquid Waste Discharge System	C2A12SA18 - Filtration of liquid discharges C2A12SA19 - Segregation and Management of Liquid Effluents C4A21 - An appropriately designed Liquid Effluent Discharge System will minimise impacts of discharges to the environment
Plant Radiation Monitoring System (KRT)	C3A16 - Selection of Methods to minimise solid waste generation C4A22 – Appropriately designed Gaseous Discharge Points will minimise impacts of discharges to the environment
Building Ventilation Systems	
Containment Sweep Ventilation System (EBA)	C2A9 - Design, construction and operation of containment systems C2A13SA24 - Filtration of Gaseous Discharges C4A19 - Preferential partitioning of radionuclides
Controlled Safeguards Building Ventilation System (DWL)	C2A9 - Design, construction and operation of containment systems C2A13SA24 - Filtration of Gaseous Discharges
Fuel Building Ventilation System (DWK)	C2A9 - Design, construction and operation of containment systems C2A13SA24 - Filtration of Gaseous Discharges
Nuclear Auxiliary Building Ventilation Systems (DWN)	C2A9 - Design and construction and operation of containment systems C2A13SA24 - Filtration of Gaseous Discharges C4A22 – Appropriately designed Gaseous Discharge Points will minimise impacts of discharges to the environment
Effluent Treatment Building Ventilation System (9DWQ)	C2A9 - Design, construction and operation of containment systems C2A13SA24 - Filtration of Gaseous Discharges
Hot Workshop, Laundry and Tank Storage Buildings Ventilation System (9DWV)	C2A9 - Design, construction and operation of containment systems C2A13SA24 - Filtration of Gaseous Discharges
Access Building Ventilation System (DWW)	C2A9 - Design, construction and operation of containment systems C2A13SA24 - Filtration of Gaseous Discharges
Annulus Ventilation System (EDE)	C2A9 - Design, construction and operation of containment systems

6 Demonstration of BAT

100. This section presents the claims, arguments and evidence that have been generated to summarise the Environment Case for optimisation through the application of BAT. Details of the methodology adopted in the production of the case are provided in Section 3.

101. Five claims have been developed to reflect the key requirements and expectations discussed above and are aligned with the optimisation requirements of the anticipated RSR environmental permit. Under these five specific claims, information is also presented where relevant to support the demonstration of BAT to minimise the amount of entrained solids, gases and non-aqueous phase liquids in radioactive liquid discharges, which is a specific condition of the RSR environmental permit template.

102. The arguments (and where applicable sub arguments) that have been prepared to demonstrate that the claim is valid have been grouped under each claim. Each argument is directly followed by the relevant evidence that has been gathered during the preparation of the case. This section has adopted a hierarchical structure to allow easy identification of claims, arguments and evidence. Links between the structure and the associated paragraph headings are represented pictorially in figures for each claim.

103. The 5 Claims are outlined below along with a brief summary of key topics that are addressed within:

- Claim 1: SZC Co. Shall Eliminate or Reduce the Generation of Radioactive Waste.
    - Specification of materials of construction for the reactor and cooling circuits to reduce the generation of radioactive waste that will require disposal.
    - Design, manufacture and efficient use of fuel during operations to minimise the amount of radioactive waste produced per tonne of fuel used in the reactor.
    - Provision of systems to manage and optimise the chemistry of the primary coolant circuit to minimise the generation and the deposition on fuel cladding of corrosion products that will subsequently become radioactive waste.
    - Design of engineered systems to limit activation where possible and contain radioactivity as close to the point where it is created; to limit its movement and migration through process and plant; and to minimise the generation of secondary wastes.
- Claim 2: SZC Co. Shall Minimise the Amount of Radioactivity Discharged or Disposed of to the Environment.
    - Design of containment systems to prevent leakage of radioactive effluent.
    - Storage of wastes containing radionuclides with short half-lives prior to discharge which allows some of the radioactivity to naturally 'decay', for example decay storage of short-lived gases on carbon delay beds.
    - Provision of abatement systems to remove radioactivity from the waste before it is discharged to the environment.
- Claim 3: SZC Co. Shall Minimise the Volume of Radioactive Waste Disposed to Other Premises.
    - Selection of abatement techniques on the basis of the high efficiency with which they remove radioactivity per unit volume of solid waste that will require disposal.

    - Selection of optimal disposal routes for wastes transferred to other premises.
    - Design to prevent / minimise discharges during operation and decommissioning, including features that will facilitate efficient decommissioning by reducing the quantity and radioactivity of activated components.
- Claim 4: SZC Co. Shall Minimise the Impacts on the Environment and Members of the Public from Radioactive Waste that is Discharged or Disposed of to the Environment.
    - Design of the liquid effluent discharge system, and gaseous discharge routes to minimise impacts on the environment and members of the public from unavoidable discharges.
    - Preferential partitioning of radionuclides to minimise impact of the environment and members of the public.
- Claim 5: SZC Co. shall undertake appropriate monitoring to check compliance with the conditions of the RSR permit.
    - Demonstration of appropriate discharge and in-process monitoring for liquid and gaseous effluents and discharge routes.

104. The claims and arguments presented in this section are based on the evidence that was available during the preparation of this Submission and relate primarily to the design of systems and components. The arguments, together with their evidence, are presented for each claim. In each case the argument is presented first, followed where applicable by sub arguments and then by sub-sections which provide the evidence for each of the main elements of each argument. References in square brackets are provided to the relevant sub-section in which the evidence appears (e.g. [Section 2.3.1.4]), for ease of reference.

6.1 Claim 1: SZC Co. Shall Eliminate or Reduce the Generation of Radioactive Waste

105. The evolutionary nature of the UK EPR^{TM} has focussed on eliminating as much of the radioactive waste at source as possible. Where elimination has not been practicable efforts have been made to minimise the activity and quantity of radioactive waste that will require subsequent management and disposal by permitted means. This is important as the elimination or minimisation at source of those materials that will become radioactive waste, is the most effective means by which environmental impacts and risks to members of the public is also minimised. This approach fulfils the requirement of:

- Condition 2.3.1 of the standard RSR environmental permit [Ref 20] states that:

> *"The operator shall use the best available techniques to minimise the activity of radioactive waste produced on the premises that will require to disposed of on or from the premises."*

The approach also demonstrates that the following Environmental and Safety Principles have been taken into account during this stage of the programme:

- Principle RSMDP3 of the RSR Environmental Principles – Use of Best Available Techniques (BAT) to minimise waste [Ref 21].
- Principle ENDP1 – Inherent Environmental Protection, such that an inherently safe environmental design avoids radiological hazards to people and the environment rather than controlling them [Ref 21].

- Principle CLDP1 – Prevention of contamination [Ref 21].
- Principle RW2 of the ONR's Safety Assessment Principles (SAPs) [Ref 22] that the generation of radioactive waste should be prevented or, where this is not reasonably practicable, minimised in terms of quantity and activity.

106. This approach is consistent with the waste hierarchy (required by Environmental Principle – RSMDP1 and Safety Assessment Principle – RW1). The approach is also fully consistent with the UK Strategy for Radioactive Discharges (2009 - 2030) [Ref 23].

107. The design of the power station proposed for SZC contains a range of features that contribute to substantiating this claim. These features are presented in the arguments that follow this claim. Those that are considered particularly important to this stage of the programme are:

- Specification of materials of construction for the reactor and NSSS to minimise the unnecessary creation and movement of activation products during power generation.
- Provision of systems to manage and optimise the chemistry of the primary coolant circuit to minimise the generation of radioactivity through activation of elements in the primary coolant (including corrosion products) that will subsequently become radioactive waste.
- The design, manufacture and management of nuclear fuel, including fuel cladding to minimise the release of fission products, tritium and actinides into primary coolant.
- Design of engineered systems to limit activation of materials and contain radioactivity as close to the point where it is created; to limit its movement and migration through process and plant; and to minimise the generation of secondary wastes.

108. In the future, consideration will be given to operational and procedural management that could minimise the production of radioactive waste and reduce the potential for contamination. If the generation of waste or contamination cannot be avoided, operational or procedural controls will be used where appropriate to minimise or mitigate the waste production or contamination. Taken together, the proposed features are expected to eliminate or reduce the generation of radioactive waste and will, therefore, make a significant contribution to minimising the activity of the waste that will eventually require disposal or discharge from SZC.

109. Figure 6-1 shows the structure of the Claims, Argument and Evidence.

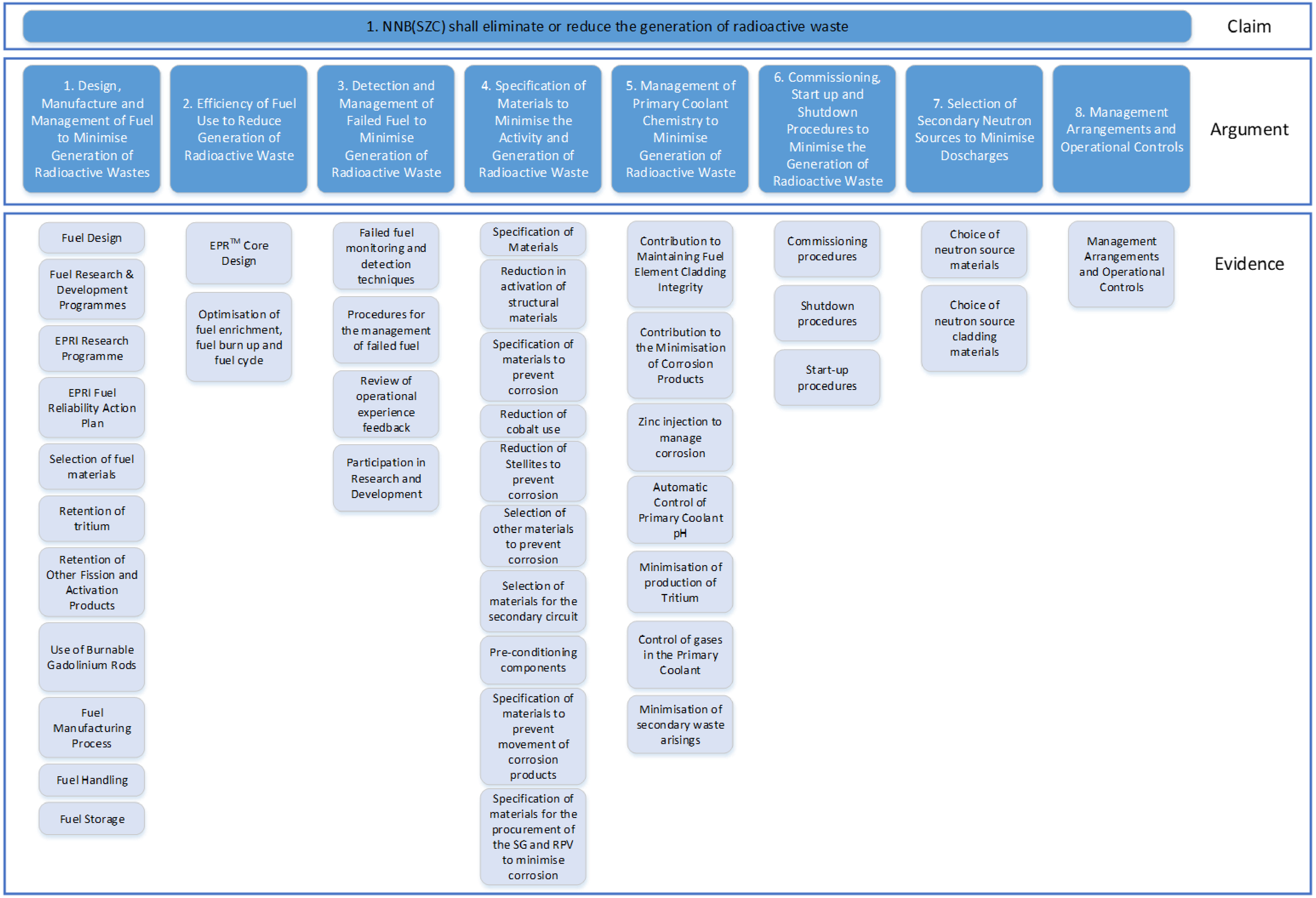


Figure 6-1 Claim 1 Structure

6.1.1 Claim 1 Argument 1: Design, Manufacture and Management of Fuel to Minimise Generation of Radioactive Wastes

110. The fuel to be used in the UK EPR^{TM} units at SZC will be uranium dioxide with 5% enrichment in uranium-235 and Zircaloy-M5 cladding. The maximum fuel burn-up is expected to be 65 GWd per te. The fuel is the largest source of radionuclides formed as a result of the controlled fission processes in the fuel rods. Ensuring that as much of the radioactivity as possible is retained within the fuel and its cladding is a key aspect of reactor design and operation, until such time when the fuel can be finally removed from the HR.

111. Aspects of fuel design and management contribute to preventing radioactivity from the fuel in entering the primary coolant and fuel storage pools water where it would require treatment as radioactive waste. These are summarised below and supported by Evidence.

- **Fuel design**. The physical integrity of the fuel rods and assemblies limits the potential for radionuclides to be released directly into the primary coolant and pool water through defects. There is an ongoing programme of international research and development aimed at continually improving the performance and minimising fuel failures.
- **Selection of materials**. Zircaloy M5 has been selected for the fuel cladding because of its corrosion resistance and low irradiation growth than the conventional Zircaloy material and its impermeability to fission and activation products. The Zircaloy M5 cladding is compatible with the high fuel burn-up rate proposed for the UK EPR^{TM} and is widely used in the nuclear industry. Gadolinium oxide has been selected as the burnable poison for the control of reactivity and is incorporated into the design of burnable poison fuel rods. The use of gadolinium oxide contributes to reducing the amount of tritium produced during the operation of the UK EPR^{TM}.
- **Fuel manufacturing process**. Fuel is manufactured to tightly controlled fuel supplier specifications to ensure high integrity and minimise the presence of residual uranium on surfaces that are in contact with the primary coolant, as this releases fission products in to the coolant during power generation. Fuel manufacturing process is important to ensure the minimisation of uranium contamination on the external surfaces of the fuel, and the release of fission products and dissemination into the primary coolant through cladding defects.
- **Fuel handling**. Fuel handling procedures ensure that the physical integrity of the fuel assemblies is maintained throughout its life and thus that the leakage of actinides, fission products and activation products is minimised.
- **Fuel Storage & Disposal** – Dry storage avoids the creation of liquid, solid and gaseous wastes associated with long term wet storage [Ref 24].

112. These measures ensure that the transfer of actinides and fission and activation products from the fuel into the primary circuit and pools water is minimised and therefore are key contributors to the minimisation of secondary wastes arising from treatment of primary coolant and pools water. The use of Zircaloy-M5 for the fuel design and manufacture is considered to be BAT. The use of burnable poisons in some fuel rods contributes to the minimisation of tritium discharges associated with the use of boron in the primary circuit and is also considered to be BAT.

a) Evidence 1: Fuel Design

113. The amount of fission products present in the primary coolant and pools water is minimised at source by high standards of fuel design and fabrication. The French technical code RCC-C Design and Conception Rules for Fuel

Assemblies of Nuclear Power Plants of Nuclear Islands [Ref 25] specifies requirements for a range of aspects of fuel design and management, including fuel system, fabrication, testing and inspection.

114. The fuel rods consist of uranium dioxide pellets stacked in a Zircaloy M5 cladding tube plugged and seal welded to encapsulate the fuel. The stack of uranium dioxide pellets extends over a height of 4.2 m known as the active height of the fuel. Above and below the uranium dioxide stack are the upper and lower fission gas plenums designed to accommodate any volatile fission products released during the irradiation process [Ref 26].

b) Evidence 2: Fuel Research and Development Programmes

115. EDF has an ongoing Research & Development (R&D) programme associated with fuel and fuel cladding, aimed at understanding the behaviour of actinides and fission products in the primary coolant, and elements in the fuel cladding. SZC Co. will have access to the results of EDF’s R&D programme and this will be used to inform the SZC project.

116. Research and worldwide OEF has also resulted in some minor changes in the fuel assembly design in order to minimise the risk of fuel assembly distortion. From a mechanical design perspective, as fuel assemblies undergo irradiation they are subject to a variety of forces both axially and laterally, as well as undergoing creep deformation. These have the combined effect of distorting the size, shape and, importantly, the straightness of the fuel assemblies within the reactor core. Fuel assembly distortion can lead to an increased risk of damaging the fuel. This could lead to an increased risk of fuel failure.

117. The modifications, presented in [Ref 27], reduce the risk of fuel distortion. Based on OEF, in particular that available through EDF SA and through The Utility Group (TUG) it is clear that minimising the risk of fuel assembly distortion is beneficial.

c) Evidence 3: Electric Power Research Institute Research Programme

118. EDF participates in a number of international research and development programmes that involve operators of power stations from around the world, such as Electric Power Research Institute (EPRI). EPRI's research programme on fuels has focussed on the most common types of mechanical failure in fuel:

- Grid-to Rod Fretting.
- Corrosion and Crud.
- Debris.
- Pellet Cladding Interaction.
- Manufacturing Issues.

119. SZC Co. will have access to the findings of the EPRI Research Programme through EDF, the results of which will inform future decisions.

d) Evidence 4: EPRI Fuel Reliability Action Plan

120. EPRI’s Fuel Reliability Action Plan is aimed at understanding the conditions leading to fuel failure and providing a basis for preventing future failures. The programme has a substantial proactive component to establish operating margins under limiting conditions (e.g. changing water chemistries) to ensure fuel operates as specified [Ref 5].

121. EDF is an active participant in two EPRI Fuel Reliability Program (FRP) Technical Advisory Committees. The (PWR) Technical Advisory Committee covers crud deposit of fuel, chemistry of primary coolant and fuel integrity. The Fuel Performance and Reliability Technical Advisory Committee covers fuel failure causes. SZC

Co. will have access to the findings of the EPRI's Fuel Reliability Action plan through EDF, the results of which will inform future decisions.

e) Evidence 5: Selection of fuel materials

122. Zircaloy M5 is a development of Zircaloy-4, which has been used previously for fuel rod cladding; the newer alloy provides for greater radiation and chemical stability (i.e. corrosion-resistance in reactor and pools water) to allow for higher burn-up in the reactor. Zircaloy M5 contains approximately 98.5 % zirconium, with approximately 1.0 % niobium, and trace iron and oxygen [Ref 26].

123. The Zircaloy M5 cladding alloy shows greater corrosion resistance and lower irradiation growth than the Zircaloy-4 material. A recent study has shown that adding up to 1% niobium to Zircaloy-4 will reduce the creep properties of the Zircaloy [Ref 28]. The levels of oxidation achieved during normal operation are very low compared to Zircaloy. The resulting hydrogen uptake is also very low. Consequentially, ductility of the fuel cladding is maintained for the proposed fuel irradiation and beyond. The cladding is practically impermeable to all fission and activation products. The Zircaloy M5 material is currently loaded into Sizewell B. It is used across the international nuclear industry and is approved for high burn-up levels.

124. Improving fuel cladding materials significantly impacts on the generation of secondary waste by limiting the release of fission products from within the fuel into the primary circuit.

f) Evidence 6: Retention of tritium

125. It has been found that tritium diffuses through stainless steel in a reactor environment at a higher rate than diffusion through zirconium alloys. Tritium also reacts with the zirconium alloy cladding to form a hydride (zirconium tritide), lessening the release of tritium to the reactor coolant. In order to minimise the production of tritium and release into the primary coolant of reactors, it is important to use Zircaloy cladding instead of stainless steel cladding, where possible (PWRs, Boiling Water Reactors (BWRs)) [Ref 5].

126. Zircaloy clad fuel, the fuel of most Light Water Reactors (LWRs), retains essentially all the tritium through the formation of zirconium tritide [Ref 29].The cladding retains the bulk of the tritium formed by fission in the fuel and tritium in gaseous effluent comes mainly from activation of boron and lithium in the coolant.

127. Although the fuel is the main source of tritium (about 600 TBq y^{-1} for a 900 MWe PWR using uranium dioxide, 700 TBq y^{-1} using Mixed Oxide, 900 TBq y^{-1} for a 1,300 MWe PWR and 1,000 TBq y^{-1} for a 1,450 MWe PWR), its contribution to tritium contamination of the primary coolant remains very low. Tritium is released from the fuels rods at a rate evaluated at less than 10^{-2}% over the lifetime of the fuel. The very low leakage from the fuel rods is due to the high affinity of the tritium for the zirconium making up the cladding and its very low diffusivity in the oxide formed on their surface (zirconia). This behaviour is not changed by adopting M5 as the cladding material. The contribution of the undamaged fuel is about 0.15 GBq per Equivalent Fuel Power Day (EFPD) for a 900 MWe PWR and 0.2 GBq per EFPD for a 1,300 MWe or 1,450 MWe PWR. It is therefore considered negligible at far less than 1 TBq y^{-1}.

g) Evidence 7: Retention of Other Fission and Activation Products

128. It is assumed in the UK EPR^{TM} GDA Pre-Construction Environmental Report (PCER) (Sub-chapter 6.3, section 6.3.1) that the fuel cladding is essentially impermeable with respect to carbon-14, a view which is supported by information in International Atomic Energy Agency (IAEA) Technical Report 421 [Ref 29] which indicates that most of the carbon-14 in fuel will pass to reprocessing plants [Ref 5].

129. Fuel cladding is designed to contain fission products in the fuel as far as possible, but a small number of fuel pins unavoidably have a small number of minute defects through which these fission products can transfer to

the primary coolant (known as “failed fuel fraction”). The majority of the fission products are retained in the fuel by the Zircaloy cladding [Ref 5].

130. For the production of noble gases, minimising the number of fuel elements used minimises the probability for cladding leakage of fission products into the primary coolant [Ref 5]. The fuel cladding is also very effective at retaining actinides within the fuel minimising the leakage of actinides into the primary coolant.

h) Evidence 8: Use of Burnable Gadolinium Rods

131. Standard operating procedure for PWRs involves injecting the primary circuit with boric acid (source of boron) to achieve primary reactivity control. According to EDF primary coolant specifications, which are also aimed at minimising corrosion, lithium hydroxide is injected into the primary circuit to maintain a specified pH range, and thus minimise the corrosion products released from the materials of construction of the primary circuit in contact with the primary coolant.

132. Natural boron contains approximately 20 % of boron-10, the remainder being boron-11. Boron-10 has a very high thermal neutron absorption cross-section (3,837 barns) whereas the cross-section for boron-11 is only 5 millibarns [Ref 5]. It is consequently a significant source term for the production of tritium.

133. Natural lithium contains approximately 7.5 % of lithium-6, the remainder being lithium-7. Lithium-6 is most significant to tritium production because it has a very high thermal neutron absorption cross-section (953 barns) whereas the cross-section for lithium-7 is only 37 millibarns [Ref 5]. Like boron, lithium is also a significant source term for the production of tritium.

134. The boron concentration can be reduced via the use of burnable neutron-absorbing materials, referred to as poisons, which are inserted with a fresh fuel load in order to lower the initial high reactivity. Due to the burnup of the absorption material, the negative reactivity of the burnable absorber decreases over core life. Use of burnable poisons reduces the required boron concentration and therefore the associated production of tritium is reduced.

135. For the UK EPR^{TM}, gadolinium was chosen as the burnable poison. This poison consists of mixing gadolinium oxide (Gd203) with the uranium dioxide in the pellets of some of the fuel rods. Studies undertaken by EDF R&D and the French Alternative Energies and Atomic Energy Commission concluded that substituting gadolinium for another poison would not provide any significant benefit. In particular, these studies showed that alternatives to gadolinium present similar capabilities in terms of control of the boron concentration. Therefore, gadolinium has been chosen as the burnable poison used in the UK EPR^{TM}.

136. In some fuel rods, consumable neutron absorber (burnable poison), in which the fuel pellets are coated with neutron absorbing boron compound or gadolinium oxide (Gd2O3), is used to control excess reactivity during the fuel cycle [Ref 26].

137. Using a significant gadolinium load of burnable poisons (number of gadolinium rods absorbing the neutrons from the nuclear reaction for new fuel loads): this reduces the required concentration of boron-10 in the primary circuit, especially at the start of each cycle (the boron-10 is used to control excess reactivity due to new fuel, over and above that which can be controlled using the reactor control rods alone). The production of tritium is reduced on a pro-rata basis. The fuel rods containing the gadolinium burnable poison have to be down rated but with the number present, this only incurs a small loss in power equivalent to about 2 days’ electricity production each year.

138. The use of gadolinium oxide burnable poison rods is taken into account in the French technical code RCC-C Design and Conception Rules for Fuel Assemblies of Nuclear Power Plants [Ref 25], which covers issues including fabrication, inspection and testing of fuel rods and fuel system design. The use of gadolinium oxide for UK EPR^{TM} fuel over boron based burnable poison is considered BAT because gadolinium oxide itself, unlike

boron based burnable poisons, is not a tritium source term and therefore has the net beneficial effect of eliminating the tritium produced from burnable poisons.

i) Evidence 9: Fuel Manufacturing Process

139. The amount of fission products present in the primary coolant is minimised at source by high standards of fuel design and fabrication. The fuel is manufactured to stringent specifications and is subject to rigorous inspection [Ref 5].

140. The specification for manufacture of the fuels ensures that external uranium contamination from fabrication processes on the external surface of the fuel is minimised. The specification and quality control on fuel also ensures a high quality of manufacture and helps in delivering fuel of high integrity. This is achieved by:

- EDF Fuel Specification. EDF will ensure that the specification of fuel, including the levels of tramp uranium, is consistent with international standards and practice.
- Manufacturing Processes. The fuel manufacturing processes adopt techniques and Quality Assurance (QA) processes that are specifically aimed at reducing tramp uranium on fuel rods and assemblies. The fuel suppliers will clean the rods and uranium pellets if the amount of uranium exceeds their standard limit. The fuel suppliers verify fabrication and tramp uranium quantity according to their own internal manufacturing standard. Fuel manufacturers also focus on improving the fuel microstructure with respect to its grain size and pore structure for minimisation of fuel failures [Ref 30].
- Inspection. EDF undertake routine inspections of fuel rods and assemblies prior to acceptance into service to satisfy itself that the amount of tramp uranium present is in accordance with the supplier’s specification. These inspections are incorporated into EDF QA Arrangements and will be incorporated into the QA arrangements for SZC.

141. Tramp uranium covers:

- Fissile isotopes which have washed out of defective fuel and have plated-out on the outside surfaces of the fuel cladding and other reactor surfaces. These fissile isotopes can fission and would also be immediately introduced into the RCP.
- Uranium impurities within the fuel cladding and other reactor materials can also fission, and the resulting fission products may leave the reactor material and end up into the RCP.
- External uranium contamination from fabrication processes on the external surface of the fuel (see above).

j) Evidence 10: Fuel handling

142. The French technical code RCC-C [Ref 25] specifies requirements for a range of aspects of fuel design and management, including fuel system, fabrication, testing and inspection. This code covers shipment, handling and storage of fuels and the precautions to be taken when handling both fuel rods and fuel assemblies, both of which will prevent damage to fuel rods and thus contribute to minimising the release of radionuclides from the fuel. This code will be taken into account in the fuel handling arrangements for SZC.

k) Evidence 11: Fuel Storage

143. The MADA study produced to assess the strategic options for the storage of spent fuel at HPC [Ref 24] concluded that all options for spent fuel storage are safe and technically feasible. The study reflected the drivers and views of those present at the decision workshop. It must be reiterated that all these options are

considered safe and are technically feasible for spent fuel storage at SZC. The main differentiator that was considered important at the workshop was the passive vs active safety systems and economic drivers.

144. The cask and canister systems scored very similarly across all categories apart from economics where the canister system was clearly preferred due to the lower unit cost and no requirement for a shielded building. Technically the pool was considered the preferred option as it is a well understood and mature system in the UK. The pool system also simplifies the inspection of the fuel and repackaging process. However, from a safety perspective the pools active system scores unfavourably with the dry storage passive systems.

145. For Environmental impact it was noted that dry storage canisters generate negligible amounts of radiological and chemical discharges. It was noted that the external dose is greater for canisters than wet storage however this is outweighed by the reduction in radiological discharges.

146. It is very important to note that the assessment did not conclude that any of the options are considered to pose a risk to the environment. All options are mature technologies with multiple safeguards and used around the world for decades. A BAT argument can be made for both wet and dry spent fuel storage options.

147. From an environmental perspective the discharges are spread across the lifetime and therefore result in a smaller contribution to the site discharge limits. The cost of dry storage is noted to be spread across the lifetime of facility operation, from a cost perspective this was considered to increase the risk.

148. The MADA was updated following Fukushima and concluded that the outcome was not changed.

149. The overall conclusions from this MADA review [Ref 24] for the particular requirements and assumptions made for the management of spent fuel from HPC at the point of review is that the preferred spent fuel management solution is dry storage in canisters although it is recognised that both wet and dry storage are suitable and safe.

150. The above assessment and evidence is based on the HPC RC2 design and safety case, the system design has been adopted as part of SZC RC0, as is described in section 2 of the RSR Application Head Document [Ref 1]. The HPC safety case presents this dry spent fuel storage solution in the Interim Spent Fuel Storage Safety Report produced [Ref 32]. It is considered that the benefit gained by replicating the system design from HPC enforces the Environment Case for dry storage. It is noted that both wet and dry storage options can be presented as BAT for the UK EPR^{TM} design and therefore potentially could be changed in the future if other (non-environmental) factors were to significantly change.

6.1.2 Claim 1 Argument 2: Efficiency of Fuel Use to Reduce Generation of Radioactive Waste

151. Reducing the production of waste (particularly so-called "long-lived" waste), for a given energy output, is key to optimising the nuclear fuel cycle from an environmental standpoint. This applies whatever the ultimate choice for long term management of this type of waste. This objective is integrated into the design and performance options chosen when planning the UK EPR^{TM}.

152. Maximising the efficiency of fuel use at SZC, when coupled with the design and manufacture of fuel, will prevent the unnecessary creation of waste and discharges by ensuring that the minimum amount of spent fuel is generated per unit of power generated. The design of the reactor core and the proposed operating regimes for fuel burn-up and fuel cycle are considered to be important contributions to the most effective and advanced stage in the development of reactor design and operation (as defined in the definition of BAT for Integrated Pollution Prevention and Control). The UK EPR^{TM} has not yet been operated, but its design and proposed fuel operating regimes are based on extensive review of OEF of other PWRs, most notably the N4 and KONVOI reactors. Whilst the EPR^{TM} at Taishan is currently operational, it is noted that operational data currently isn’t available. When it becomes available, it will be reviewed and incorporated as appropriate. Capture of OEF is covered by [SZC RSR CMT1] of the forward work plan of the SZC permit application head document [Ref 1].

153. The key aspects which contribute to the efficiency of fuel use which are:

- UK EPR^{TM} core design. This has evolved from experience gained on existing reactors. The UK EPR^{TM} units are designed to achieve a significant increase in power output per unit mass of fuel used in comparison with earlier reactor designs.
- Optimisation of fuel use, taking account of enrichment and fuel cycle, to reduce the amount of fuel per unit of energy produced. This includes increased burn-up and increased flexibility to implement various types of fuel.

154. The gain in overall fuel efficiency (natural uranium) in the UK EPR^{TM} compared to N4 units, in view of the expected fuel characteristics in the medium-term, thus reaches 22 % for an equivalent energy generation. The design, combined with the improvement in its output is a strong feature of the UK EPR^{TM} reactor. There is more efficient use of natural uranium resources, better use of irradiated fuel in the reactor, a significant reduction in the long lived radioactive waste produced by the fuel and its cladding, and better in situ use of plutonium.

155. Increased burn-up implies that the fuel is used more efficiently and that the quantity of spent fuel generated will be smaller per unit of electricity produced. However, increased irradiation leads to individual fuel assemblies with an increased concentration of fission products and higher actinides. This means that the efficiency of fuel use, in terms of reducing radioactive waste arisings, also depends on the robustness of the fuel cladding in retaining fission products and actinides in the fuel during both reactor operation and subsequent storage. The role of the design and manufacture of fuel in minimising radioactive waste arisings is discussed in Argument 1.

156. The more efficient use of fuel will also minimise the amount of spent fuel arising from operation of SZC. This will reduce the secondary wastes associated with spent fuel management. Reduced refuelling requirements and optimising fuel cycle length will reduce the amounts of secondary radioactive wastes associated with refuelling operations. Assumptions regarding waste generated are based on a conservative assumptions of a consistent 18-month fuel cycle, however it is possible to optimise the fuel cycle length between 18-22 months to allow for operational contingencies and optimisation of outage dates.

a) Evidence 12: UK EPR^{TM} Core Design

157. With regards to its core design and its use of fuel, the UK EPR^{TM} reactor presents a number of evolutions developed thanks to previous experience of existing reactors. In particular, compared to existing plants, the UK EPR^{TM} enables better overall use of the fuel material as a result of increased operating and safety margins and more efficient use of the neutrons produced. Hence, it follows that there is less use of nuclear material to produce the same amount of energy. It is thus possible to reduce both the consumption of natural uranium and the quantity of waste produced by irradiation, for the same amount of energy produced.

158. Key aspects of reactor core design that are relevant to the efficiency of fuel use include:

- Adoption of a "large core" comprised of 241 fuel assemblies, compared to the 205 elements of the N4 units, for comparable electrical output. The yields achieved have the following physical bases:
  - reduction in neutron leakage due to the increased size of the core; and,
  - additional assemblies leading to a 9% reduction in the linear power density of the core at nominal power. This enables neutron poisoning due to xenon to be reduced and above all, a smaller fraction of the core to be refuelled, for a given burn-up and operating cycle length.

159. Overall, with the minimum 18-22 months operating cycle, taken as the reference, the improvements linked to the adoption of the "large core" with its smaller refuelling fraction requirement enable savings in natural uranium of the order of 7%. Also, the additional margins of the “large core” enable so-called ‘low leakage” loading patterns to be adopted, which contribute to better fuel use by the reduction of radial neutron leakage.

- The use of a solid steel reflector called the "heavy reflector". The reduction in radial neutron leakage it generates, once again, leads to savings of 2 to 3% of natural uranium consumed for a given energy output.

160. The improvement in the overall thermal efficiency, and in particular the enhanced turbine efficiency, contributes 5% to the reduction in the consumption of uranium.

161. The use of the heavy reflector in the UK EPR^{TM} results in additional arisings of ILW in comparison with other reactor designs which do not incorporate a heavy reflector. However, the heavy reflector is also of benefit in extending the lifetime of the reactor vessel by reducing its irradiation by neutrons. For a given quantity of energy produced, the proportional reduction in the quantities of irradiated assemblies produced, as a result of the improvement in fuel use, enables the overall quantities of irradiated materials in the reactor to be reduced.

b) Evidence 13: Optimisation of fuel enrichment, fuel burn-up and fuel cycle

162. Management options considered in the design phase of the UK EPR^{TM} correspond to the optimum of what can be envisaged today using current fuel products; i.e. an average burn-up in discharged assemblies of 60 GWd per te, which can be compared to the typical PWR average burn-up of 45 GWd per te currently achieved. “High burn-up” management methods, which optimise the use of the fuel, are facilitated by the UK EPR^{TM} design and allow savings of approximately 7% of the natural uranium resources required compared to current fuel for a given amount of energy produced. Increased burn-up and increased flexibility to implement various types of fuels. A reduction in the residual quantity of plutonium produced inside the fuel assemblies in the reactor during the cycle should be noted. This arises from better use (- 15%) of plutonium by burn-up in the cycle, which contributes 40% to the overall energy produced.

163. For a given quantity of energy produced, the proportional reduction in the quantities of irradiated assemblies produced, as a result of the improvement in fuel use, enables the overall quantities of irradiated materials in the reactor to be reduced.

164. The use of higher enrichment and increased fuel burn-up results in higher decay heat levels, which require longer storage periods in spent fuel pools prior to transfer for interim safe storage. The use of higher burn-up for fuel in general is expected to increase the degree of corrosion of the zirconium alloy cladding. However, the new Zircaloy-M5 alloy which will be used in the fuel cladding for the UK EPR^{TM} has significantly reduced corrosion rates compared to zirconium alloys previously used and thus will support achievement of higher burn-up rates, as discussed in Argument 1 Design, Manufacture and Management of Fuel [Ref 31].

6.1.3 Claim 1 Argument 3: Detection and Management of Failed Fuel to Minimise Generation of Radioactive Waste

165. Fuel cladding is designed to contain fission products in the fuel as far as possible, but a small number of fuel pins unavoidably have a small number of minute defects through which these fission products can transfer to the primary coolant (known as “failed fuel fraction”). The majority of the fission products are retained in the fuel by the Zircaloy cladding [Ref 5].

166. The reactor is operated in such a way as to minimise the risk of fuel failure to contain fission products and fissile material in the fuel rod. However, it is necessary for the condition of fuel to be monitored during operations (including start-up and shutdown) to detect failed fuel. This enables for appropriate action to be taken to

minimise the activity introduced into the primary coolant as a result of fuel failure, which places an additional burden on primary coolant management. Following removal from the reactor, additional measures will be in place to detect and manage fuel cladding failures during long-term storage of spent fuel in the Interim Spent Fuel Store (HHK). The measures taken to detect and manage failed fuel to minimise the discharge of activity into primary coolant, fuel building pool and dry storage cask are:

- Failed fuel monitoring and detection techniques. The condition of fuel during reactor operation is monitored by means of the monitoring of primary coolant activity levels. This rapidly detects failed fuel on the basis of the presence of increased fission products (primarily short-lived xenon and iodine isotopes). The condition of spent fuel when it is placed into a dry storage cask is checked by measuring the level of radioactivity in the accompanying pool water, prior to draining the cask and commencing the drying activities. During the drying process the levels of radioactivity within the cask continue to be monitored to confirm no fuel failures. Failed fuel is not knowingly loaded into the cask and the very dry inert atmosphere within the cask provides no degradation mechanism that would lead to a fuel cladding failure. The loading of failed fuel into the cask is reversible providing a means to physically inspect the fuel should it be deemed necessary at some point during the storage [Ref 32].
- Procedures for the management of failed fuel. The actions to be taken in the event of detection of failed fuel are based on EDF’s Operating Technical Specification. In order to minimise the release of fission products caused by fuel leaks, leaking fuel pins are located during refuelling and not reused Failed fuel will be bottled prior to placement in the dry storage casks [Ref 32].
- Review of OEF. EDF uses a computer programme (MERLIN) to capture, test, validate and analyse chemical and radiochemical data from all reactors. This includes monitoring of the fuel performance of every French unit. This includes the analysis of fission product activities to detect and characterise fuel cladding defects during the operating cycle.
- Research and Development. EDF has carried out an exhaustive analysis of reactor primary coolant activities in order to enhance its knowledge about fission product behaviour and thereby improve failure diagnosis. The MERLIN code developed by EDF is used by the French utilities to predict the characteristics and number of failed rods. This is part of a broader programme of R&D being carried out by EDF aimed at understanding fuel failures and their consequences in terms of the behaviour of radionuclides, including actinides, released into the primary coolant and how these can be most effectively minimised to protect workers and minimise discharges of activity into the environment.

167. SZC Co. will take advantage of the benefit of EDF’s experience in detection and management of failed fuel, including their operational experience to optimise performance at SZC.

a) Evidence 14: Failed fuel monitoring and detection techniques

168. Primary coolant activity monitoring is the main method used by utilities to rapidly detect and characterise fuel cladding defects. The relevant isotopes activity level and isotopic ratios are the main parameters for detecting the onset of failures and for identifying the nature of the failed rod or its characteristics such as burn-up, power and defect localisation.

169. A fuel defect appearance has an impact on fission product activity levels in primary coolant and their ratios. The xenon-133 activity increases compared to the releases from other shorter lived fission gases (like xenon-135 or xenon-138) and this is the best way to detect the presence of defects. In contrast, iodine activity levels do not generally give any warning of the presence of leaking rods. In most cases the start of a defect is accompanied by an increase in fission noble gases and a xenon-133/xenon-135 inversion without any modification of iodine activities. During steady–state reactor operation the iodine is commonly trapped inside

the defect. Taking into account these elements, the criterion chosen by EDF to determine defect onset is based on the xenon-133/xenon-135 values.

170. In EDF Radiochemical Specifications a xenon-133/xenon-135 value greater than 0.9 is considered to be an indicator of the presence of fuel defects [Ref 33].Dry storage of spent fuel relies on a double barrier containment of the fission products. This double barrier is made up of the fuel cladding and the Multi-Purpose Container (MPC). Spent fuel is monitored to ensure there are no signs of failure prior to commencing drying activities. During the process of drying the levels of radioactivity in the cask are monitored to confirm there are no fuel failures. Failed fuel is not knowingly loaded into the cask and the very dry inert atmosphere within the cask provides no degradation mechanism that would lead to a fuel cladding failure once in storage. The loading of failed fuel into the cask is reversible providing a means to physically inspect the fuel should it be deemed necessary at some point during the storage [Ref 32].

b) Evidence 15: Procedures for the management of failed fuel

171. Operations with fuel failure are carried out if the activity limits specified in the operating technical specifications are not reached. The parameters of primary coolant activity are bounded by the indicators. 3 levels of actions are specified, namely close surveillance and interruption load follow, shutdown within 48 hours, or shutdown within 8 hours. In the event that a cycle is carried over until the end with fuel failures, a new cycle it is not permitted to start with fuel defects. Therefore, assemblies with fuel defects are removed during shutdown. Cycle operations stop if the activity limit permitted of fission product indicators in the primary coolant is exceeded. The fuel assembly is removed, and fuel cycle cannot be restarted if it is defective. The reloading of failed assemblies is not permitted.

172. The fast detection system of a failed fuel assembly is carried out during shutdown. The fuel assembly is removed, and a sipping test is undertaken during fuel discharging to detect failed fuel assemblies using the mast sipping equipment. Therefore, assemblies with fuel failures are identified via the sipping tests and removed during the shutdowns. Examination of post-irradiated fuel is only carried out if there are fuel defects or if a new product is used.

173. In order to ensure adequate cooling of failed fuel assemblies in the fuel building pool, the bottled fuel will not be sealed, but they will be fitted with filters that will capture any radioactive particulate released from the failed fuel before it can escape into the main body of pool water.

174. Failed fuel is not knowingly loaded into a dry storage cask and the very dry inert atmosphere within the cask provides no degradation mechanism that would lead to a fuel cladding failure [Ref 32].

c) Evidence 16: Review of Operational Experience Feedback

175. EDF has carried out an exhaustive analysis of reactor primary coolant activities in order to enhance its knowledge about fission product behaviour and thereby improve failure diagnosis. The MERLIN code, developed since the 1990s by EDF, is used by all EDF Nuclear Power Plants (NPP) as a management application in order to capture, test, validate and analyse the data from each reactor relating to chemistry and radiochemistry parameters. EDF is able to monitor the fuel performance of every French unit. This monitoring includes the analysis of fission product activities during steady operation, transients and shutdowns.

176. EDF feedback has been exhaustively analysed to improve failure diagnosis and thus help the NPP in its decisions concerning the planning of transient periods, shutdowns and sipping tests [Ref 33]. Such OEF will continue during the next phases of SZC development and once operational, SZC will contribute to this feedback, as will HPC. Further information regarding SZC Co. plans to utilise OEF are detailed in [SZC RSR CMT1] of the forward work plan in the SZC permit application head document [Ref 1].

d) Evidence 17: Participation in Research and Development

177. EDF has an ongoing R&D programme associated with the fuel and fuel cladding. This includes the behaviour of actinides and fission products in the primary coolant, and elements in the fuel cladding. This is aimed at understanding the aqueous chemistry of actinides and fission products in the primary coolant. It is needed to improve the purification systems and propose the best physical and chemical conditions to retain these elements in the resins and/or filters and thereby minimise releases to the environment [Ref 34].

178. EPRI's Fuel Reliability Action Plan is aimed at understanding the conditions leading to fuel failure and providing a basis for preventing future failures. The programme has a substantial proactive component to establish operating margins under limiting conditions (e.g. changing water chemistries) to ensure fuel operates as specified. In addition, there is a separate programme in the fuels area called Nuclear Fuels Industry Research to conduct basic fuel research [Ref 5].

179. EDF is an active participant in two EPRI FRP Technical Advisory Committees. The PWR Technical Advisory Committee covers crud deposit of fuel, chemistry of primary coolant and fuel integrity. The Fuel Performance and Reliability Technical Advisory Committee covers fuel failure causes. EDF therefore contributes to international efforts in minimising fuel failures and the learning will be applied by SZC Co.

6.1.4 Claim 1 Argument 4: Specification of Materials to Minimise the Activity and Generation of Radioactive Waste

180. The principal drivers for optimisation of the UK EPR^{TM} design with respect to source term reduction or minimisation are the need to reduce worker radiation doses during reactor operations, maintenance and decommissioning to As Low As Reasonably Practicable (ALARP) and the reduction of environmental impacts and solid radioactive waste arisings. There are two main issues associated with the specification of materials for SZC, particularly those materials to be used in the NSSS, and their potential to minimise activity at source, which are described below.

i. Activation of structural materials by neutron flux.

181. Materials inside and close to the reactor core have the potential to become activated by neutrons within the core. Once materials have become activated, they will require management and eventual disposal during the decommissioning process. Highly activated materials are more difficult to deal with in terms of worker dose, treatment and method of disposal, and therefore it is considered BAT to minimise generation at source wherever possible.

182. Particularly susceptible materials to activation are those which contain a significant percentage of metals such as cobalt. The isotopes cobalt-58 and cobalt-60 contribute on average over 90 % to the dose rate in NPPs in France. This also applies to the UK EPR^{TM}, although accessibility inside the HR during power operation slightly modifies the dose contributions as access is only available during outages so as to minimise exposure of operators. Cobalt-60 has a half-life of 5.27 years, resulting in highly active materials remaining for a significant length of time after cessation of generation. These materials will be reduced or replaced in the NSSS in the UK EPR^{TM} design used at SZC, where practicable, with materials which are less susceptible to activation. In this instance there is alignment between the requirement to ensure dose to operators is ALARP, and the requirement to ensure the generation of future decommissioning wastes represents BAT, and the minimisation of activation is key in ensuring the design represents both BAT and ALARP. A heavy reflector which is made of austenitic stainless steel provides protection to the reactor pressure vessel core shell against radiation embrittlement and reduces its activation.

ii. Movement and activation of corrosion products.

183. As the coolant water circulates around the primary circuit of a PWR, it corrodes the metallic components with which it is in contact. Although the rates of corrosion are very low, the processes play an important part in the creation and distribution of radioactive isotopes in the reactor. Some of the products of corrosion and of metallic components become suspended or dissolved in the coolant water and are then transported around the primary circuit. Some of them are then deposited in the core of the reactor, where the high neutron flux results in them being 'activated', i.e. radioactive isotopes are created within the deposited corrosion products by the action of neutrons. Deposited activation corrosion products generate a radiation field that is the greatest contributor (around 85 %) to the radiation dose to power station staff during shutdown and maintenance operations. Some of these activated corrosion products become resuspended or re-dissolved in the coolant water, and are once again transported around the primary circuit, where some are then redeposited in out-of-core regions of the circuit.

184. Corrosion products will form from the structural materials in both the primary and secondary circuits. This can be significant if materials are particularly susceptible to corrosion. If the primary and secondary circuits become corroded, cracks may occur leading to:

- activated corrosion products escaping into and contaminating the otherwise clean secondary circuit; and
- corrosion products from the secondary circuit migrating across to the primary circuit where they have the potential to become activated.

185. The clean-up and abatement of the activated corrosion products will result in the production of secondary wastes. Abatement techniques are discussed under Claim 2.

186. Materials which are susceptible to corrosion and/or activation such as cobalt, Stellites (that have high cobalt content), antimony and silver will be replaced, where practicable, with materials which have a similar or greater resistance and lower activation capacity. A materials specification for limiting the use of cobalt has been developed which is used for existing EDF sites and the UK EPR^{TM}.

187. The removal of a high percentage of the Stellites is possible because the hard-facing property it is used for is only required for valve designs where metal surfaces are in intimate contact under high stress. Therefore, where this property is not required, Stellites have been replaced where practicable with a cobalt-free material with similar mechanical characteristics, or, in some cases, by an adequate nickel base product.

188. Chromium is present in the alloys used in the primary circuit and is important for corrosion resistance. However, like Stellites, chromium can corrode and become activated by neutron flux. Given its very short half-life (27.7 days) in comparison to in particular Cobalt-60 (5.27 years) the contribution of chromium-51 is considered to be minimal and further reduction is not practicable.

189. Sources that can corrode and give rise to isotopes such as silver-110m, antimony-124 and antimony-122 in the coolant will be eliminated or reduced as far as practicable, e.g. the reduction in helicoflex seals for graphite seals and greater use of rotor stops and bearings without antimony.

190. The secondary circuit is clean, and it is important it remains as such to prevent contamination and production of radioactive waste. This will be achieved by a combination of two fundamental design choices with respect to specification of materials:

- The absence of copper materials, which are known to be susceptible to corrosion in the presence of ammonia and whose corrosion products can increase the risk of corrosion to ferrous materials when transported within the system.

- The use of low chromium steel for elements that are highly sensitive to the flow accelerated corrosion phenomenon (diphasic water/steam medium).

191. In addition to replacing materials with alternatives less likely to become activated and corroded, corrosion can be further reduced by preconditioning those components expected to be most susceptible. The two most widely used processes are electro-polishing and the stabilised chromium process. Further information on these technologies can be found in the Radiation Control Field Report [Ref 35]. The coatings act as a barrier to reduce corrosion and also to prevent any activated particulate from separating and moving in the system to contaminate other parts of the plant.

192. Leak tightness is important in restricting the movement of corrosion products within and outside the reactor systems, in particular the primary coolant system. This will limit the activity which leaves the system and therefore requires further treatment prior to discharge. Materials can be specified to reduce the risk of leakage. Active parts on the system (pumps and valves) are more susceptible to leaks and will therefore be targeted. Specifically, the pumps in the REA which will be of the canned rotor type.

193. The evolution of the UK EPR^{TM} design has benefited from decades of Light Water Reactor research, development and operational experience in France and internationally, through participation and collaboration with other LWR operators and academic organisations [Ref 5]. The information relevant to SZC has been drawn from this information and is presented in the argument above.

194. Undertaking measures to reduce activation and corrosion where practicable in the SZC design seeks to minimise activity at source which reduces the need to rely on minimised discharges and waste. However, it is important to understand all the characteristics of materials, such as cobalt, which were chosen in the first place and why these characteristics are important in the design. This is to ensure that the replacement material provides an equal or enhanced performance in all areas. The specification of materials to prevent activation and corrosion and thus minimise radiation doses to workers and radioactive waste arisings is a key element of demonstration of BAT.

195. NNB GenCo (HPC) completed a report on ‘The Use of BAT to Minimise Production of Activated Corrosion Products Considering Improvements from GDA’ [Ref 36] to close out HPC IC8 arising from the HPC permit application, and GDA assessment finding UKEPR-AF04. A qualitative approach based on logical reasoned argument was appropriate for the BAT assessment methodology. It assessed how BAT was applied to the design and specification of Steam Generator (SG) tube nickel content; EP of SG heads; cobalt content of steel in the primary circuit and Stellite content of components (further details in Evidence 20, 21, 24 and 26). The report applied Environment Agency guidance and the NNB GenCo (HPC) Environmental Optimisation Standard to complete a risk informed assessment balancing the benefits and detriments associated with the doses from discharges and impact on waste arisings classifications and showed it resulted in very small impacts.

196. The replication strategy employed for SZC and the replication of the design of the HPC nuclear island for SZC means that the application of BAT in this context is also relevant for the SZC design, and the HPC IC8 report is considered applicable to SZC in full.

a) Evidence 18: Specification of Materials

197. This applies to all materials irradiated either directly or through their corrosion products. With regard to reduction of dose rates, the principal measures adopted at the design stage include:

- elimination wherever possible of cobalt, for example, by reducing wear through design modifications, and by replacing materials with a high cobalt content level (Stellites) by alloys without cobalt. Activated cobalt (in the NSSS) constitutes the main source of dose during operation and the main source of dose during decommissioning;

- the use of alloy 690 for the SG tubes minimises the quantity of cobalt in the corrosion products circulating in the primary system. It also reduces the risk of leakage of radioactive species from the primary circuit to the secondary circuit by the virtue of its significant resistance to stress corrosion cracking;
- limiting the amount of cobalt in steel and alloys and the replacement of seals coated with silver by graphite seals (an isotope of silver represents a significant source of dose during the first few years after the shutdown of a unit);
- limiting seals and bearings made with antimony; and
- provision of heavy reflector to minimise activation of components.

198. In order to limit the source term of radioactive pollutants, particular care has been given during the conception stage of the UK EPR^{TM} to the specification of all materials in contact with the primary effluent in the primary circuit. These materials include cobalt and Stellites, silver, antimony and molybdenum which are highly susceptible to activation and porous materials which can become readily contaminated.

b) Evidence 19: Reduction in activation of structural materials

199. The reactor design includes neutron shielding. This shielding reduces the activation of materials and thereby facilitates the clean-up of the structures while reducing the volume of active waste. This involves:

- the neutron shield (also referred to as 'heavy reflector') surrounding the core, made of a dozen circular elements joined together by vertical tie-rods; and
- the slab positioned above the vessel, made of removable concrete plates.

200. This shielding is unavoidably activated during reactor operation to a significant degree but is designed to be dismantled in sections. This makes it possible to remove it once commercial operation of the reactor has ceased, while exposing workers to the minimal dose.

c) Evidence 20: Specification of materials to prevent corrosion

201. The choice of materials in the UK EPR^{TM} is adapted to the intended conditions of use, which include in particular the applied loading (i.e. amplitude and potential cyclic variations), operating temperatures and environmental conditions which may impact the ageing modes of the components, including the evolution of the physical properties of materials and the various types of corrosion [Ref 37].

202. The main metals with which the coolant water in a PWR comes into contact are stainless steel and Inconel (an alloy principally of nickel and chromium). Another metal, Stellite (an alloy principally of cobalt and chromium), is present in smaller amounts, but is important in the production of activated corrosion products. Reactions between neutrons and stable isotopes of major and minor components of these alloys that are contained in corrosion and erosion products create a great many different radioactive isotopes. Some of these radioactive isotopes have relatively short half-lives and emit high energy gamma radiation, such as cobalt-60. These are particularly important because they create radiation fields that are a major contributor to worker doses when activated corrosion products are redeposited in out-of-core regions of the primary circuit. Other radioactive isotopes have longer half-lives and do not emit high energy gamma radiation, such as nickel-63, but can still be important when it comes to assessing the effects of effluent discharges and waste disposals.

203. It is known that cobalt-58, cobalt-60, silver-110m, antimony-122 and antimony-124 can all contribute significantly to primary circuit contamination. Therefore, special attention has been given to the selection of primary circuit materials in order to limit these precursors present as a constituent of base metal or as impurities. The selection of cobalt containing components has followed an ALARP approach, in particular with

regard to the optimisation or suppression of Stellite, and the decrease of cobalt residual content in the primary materials. In this instance, the ALARP approach to minimise dose to the operator, will also result in minimisation at source of waste generated, and therefore also represents BAT. An AREVA (now Framatome) report was produced [Ref 37] demonstrating that the manufacturing processes of main primary circuit materials is optimised regarding to corrosion phenomena resulting in minimisation of primary circuit contamination.

204. All parts of the Chemical Volume and Control System (RCV) (piping, valves, and components) that are in contact with the primary coolant are made of austenitic stainless steel. Parts of the RCV that are not in contact with the primary coolant may be constructed of materials other than austenitic stainless steel (e.g. pump motors).

d) Evidence 21: Reduction of Cobalt Use

205. Efforts are being made to ensure that the cobalt content of all materials will be minimised according to ALARP principle. On this topic of reducing cobalt content to minimise generation of waste at source the goal of an ALARP assessment to minimise dose to workers, is aligned with that of BAT, to minimise impact to the environment. A materials specification has been developed which is used for existing sites and the UK EPR^{TM} [Ref 39]. The specification limits the cobalt content for SG tubing, bulk austenitic stainless steel, welding materials and other miscellaneous steels. It applies to those materials which come into contact with primary coolant at operating pressure and temperatures or are used in primary coolant injection systems [Ref 5].

206. The materials specification considers a number of factors to achieve cobalt contents which are in accordance with ALARP principles. These include the release rate of corrosion products and cobalt residual content of materials, as well as the surface of materials in contact with the primary coolant. Consideration of these factors enabled optimisation of the potential release of corrosion products from materials and the extent of surfaces concerned [Ref 37].

207. 'The Use of BAT to Minimise Production of Activated Corrosion Products Considering Improvements from GDA' [Ref 36] assessed the specification of low cobalt content materials for reactor construction materials. A review of all the radionuclides within the primary coolant highlighted limiting the production of Co-60 as particularly important in terms of radiological protection and waste classification for decommissioning. Co-59 is also present in very low levels (<0.3%) in typical grade steel and nickel alloys for non-nuclear applications.

208. The high decay energy and specific activity of Co-60 means that limiting the Co content within the NSSS materials will have significant impact in reducing worker dose and will make a small but positive difference to the dose to the public. The low levels of Co-59 do not contribute to the level of activated corrosion products and so reduced cobalt content will not reduce the volume of waste.

209. The greatest savings are realised by specifying lower cobalt content in materials with a large surface area and in areas of high neutron flux. Materials which have a low surface area or experience low neutron flux will make insignificant relative contributions to the Co-60 production within the NSSS, and more typical grades of material may be suitable.

210. Constant improvements are being made in the construction of SG tubes in 690TT alloy. It should be noted that 690 alloy was chosen over 800 alloy on stress-corrosion resistance and on overall steam-generator design. Recommendations aiming at optimising the behaviour of the 690TT alloy in terms of dose uptake have been associated with this choice (see Chapter 12 of Pre-Construction Safety Report (PCSR)) [Ref 40]: "The Ni-base Alloy 690TT tubing is the preferred material replacement for PWR SGs and can readily be supplied with an average cobalt content of less than 150 parts per million (ppm) and a maximum value of 200 ppm for any one heat" [Ref 35]. The RCC-M code [Ref 59] and final specification will describe the final requirements for the specification of materials.

211. Experience from French NPPs reflects that decreasing the nickel content in the SG tubing significantly decreases cobalt-60 contamination. This is true to a certain extent since operational experience also reveals that below a certain threshold, the cobalt content in the SG tubing has less impact on cobalt-60 contamination levels [Ref 59].

212. SG tubes make up 85% of the total surface area wetted by the primary coolant. The nickel content of SG tubes has been optimised through the selection of 690TT steel to minimise the risk of stress corrosion cracking, consistent with relevant good practice and the application of material specifications that are in-line with established international code (RCC-M). This is covered in more detail in Evidence 26 (Section 6.1.4.9).

213. The remaining materials constitute <15% of the total surface area wetted by the primary coolant. The cobalt within these materials are therefore less significant in terms of contact area, and the cobalt specifications are based on their location within the NSSS and hence their exposure to neutron flux. The required cobalt limit stipulated by the RCC-M standard varies depending on whether the wetted surface area is more or less than 1m^2 and on the neutron flux as listed in Table 6-1 below:

Table 6-1 Cobalt limits applied to system types by the RCC-M standard

Type of System	Nuclear pressure equipment		Max Co content (%)		
			UK-EPR^{TM}	RCC-M	EPRI
First Equipment Classification category for radiation protection (CPP-AR): the Reactor Coolant Pressure Boundary (CPP [RCPB])	RPV Forgings	Core Shell	0.02	-	-
		Other (base & welds)	0.03	0.03	0.02 / 005
	Areas subject to high neutron flux	Austenitic materials (base & welds)	0.06	0.2 (0.1)	0.05
		Reactor internals (base material)	0.06	0.2 (0.1)	0.05
	Areas not subject to high neutron flux (base, welds, safe ends & cladding	Austenitic materials	0.1 (0.06)	0.2 (0.1)	-
		Ni-Cr-Fe alloys	0.1 (0.06)	0.2 (0.1)	-
	SG	Tube bundle	0.035 (0.015)	0.035 (0.018)	0.020 (0.015)
	Other in contact with primary coolant		0.2	-	-
	All equipment where combined wetted surface area per unit is <1m^2		0.2	-	-
Second Equipment Classification Non CPP [RCPB] All connected systems injecting fluid into the RCPB	Austenitic materials and Ni-Cr-Fe alloys (base, welds, safe ends & cladding)		0.2 (0.1)	0.2 (0.1)	-
	All equipment except the above		0.2	-	-
	All equipment where combined wetted surface area per unit is <1m^2		0.3	-	-

214. ‘The Use of BAT to Minimise Production of Activated Corrosion Products Considering Improvements from GDA’ [Ref 36] assessed the limits specified in RCC-M. and the table above against the EPRI requirement that cobalt content be ‘as low as possible’, ≤0.02% Co for Inconel alloys, and ≤0.05% Co for stainless steel; with no guidance of the relative surface area or position within the NSSS. For high neutron-flux areas, the RCC-M code is

considered to be largely in-line with EPRI guidance. Where the specification is higher than EPRI it is by 0.01% which is likely to have a negligible effect. The limits adopted are therefore considered to represent BAT.

215. By considering the surface of materials in contact with the primary coolant, the release rates of corrosion products and their probability of activation in the core, it was found possible to decrease the Cobalt-60 source term in the UK EPR^{TM} primary circuit as far as was reasonably practicable.

216. Based on experience from German NPPs on progressive reduction of Stellite content, the dose rate is relatively insensitive to Stellite content when the global surface in contact with the primary coolant is below about 2m^2. This contact area achieved for the UK EPR^{TM} is estimated to about 1.9 m^2 (Control Rod Drive Mechanism (CRDM) excluded). Therefore, the doses in the vicinity of primary components should be in the same range as for the latest generation of German NPPs and the design approach is considered to be consistent with the ALARP principle [Ref 37].

217. [Ref 36] determined that the cobalt content of the steel used in the primary circuit at SZC has been optimised through the application of established international codes and standards and is consistent with relevant good practice seen at some of the best performing nuclear power stations in the world.

e) Evidence 22: Reduction of Stellites to prevent corrosion

218. Stellites are cobalt–based alloys with hard-facing characteristics. However, when a Stellite-coated surface becomes worn out, particles are likely to detach from it and flow within the primary liquid towards the reactor core, where the cobalt content of the alloy becomes activated, producing highly-dosing cobalt-60 to further deposit as “hot spots”.

219. Laboratory investigations confirm that cobalt-based hardfaced alloys provide the highest resistance to adhesive (galling) wear. However, this attribute is only necessary in valve designs where metal surfaces are in intimate contact under high stress. Therefore, the use of cobalt-based hardface alloys should be limited to large gate valves, with hardenable martensitic 400 series alloys or iron-based hardface alloys specified for globe, swing check, and flow control valves. The primary degradation mechanism in these valves is corrosion and/or cavitation-erosion damage, and many cobalt-free alloys are available that can provide this attribute [Ref 35].

220. Stellites will be replaced where considered practicable by a cobalt-free material with similar mechanical characteristics, or, in some cases, by an adequate nickel base. These alternative materials are currently undergoing tests. One material, NOREM, is emerging as the most suitable replacement and “EDF continues to view NOREM as holding promise to serve as a replacement for Stellite 6 and tests of other valves with NOREM are taking place” [Ref 35].

221. With regard to the Stellite-containing surfaces in the internal core support structures, optimisation measures are still currently being developed by EDF/AREVA. These surfaces will be reduced as much as possible in comparison to the current French PWRs and only surfaces with high mechanical-load will be coated with Stellites. It is expected that this will lead to a 4 % reduction of the total dose for the UK EPR^{TM}.

Experience from German NPPs reflects that dose rates are relatively insensitive to Stellite content when the global surface of materials in contact with the primary coolant is below a certain value (2 m^2) [Ref 37]. This surface will be reduced in the UK EPR^{TM} as much as possible and be below this threshold. ‘The Use of BAT to Minimise Production of Activated Corrosion Products Considering Improvements From GDA’ [Ref 36] assessed evidence for the reduction and minimisation of Stellite in the UK EPR^{TM} design. Components which contain Stellite materials within the UK EPR^{TM} NSSS are:

- Control Rod Drive Mechanisms (CRDM) - The design of the CRDMs and core instrumentation are as for KONVOI reactors, which are considered the most optimised with regards to stellite content, and therefore best practice. The UK- EPR^{TM} CRDMs contain Stellite-6 and Haynes25 (also a cobalt based alloy) and have been qualified with tests (at the KOPRA component test facility) for the 60 year UK EPR^{TM} design life (+50% margin, giving a total of 9 million steps). No alternative material has undergone similar stringent qualification.

- RCP Main Coolant Pumps (MCP) - The MCPs and RPV internals are as for the N4 design, and here the designs have been optimised to reduce the Stellite surface area. The MCP retains Stellite-12 in the back seat and auxiliary hydrodynamic bearing. Stellite reduction has focused on the auxiliary bearing which is used during start-up, shut-down and accident conditions, whereas the back seat is only used during maintenance operations and is not in contact with the coolant [Ref 16] [Ref. 7]. The Stellite surface area within the UK-EPR^{TM} RPV components will be larger than the KONVOI design but the relative surface area is higher within the UK- EPR^{TM} design. No alternative to Stellite for the components within the RPV internals has been tested for the UK- EPR^{TM} to demonstrate suitable performance. An alternative material may result in increased waste volumes, and as even the Stellite material has shown evidence of wear, an alternative material is likely to lead to a requirement for more frequent replacements which will contribute to both operator dose and waste volume.

- Reactor Pressure Vessel (RPV) Internals - The Stellite content of the RPV internals have been reduced by consideration of the static and dynamic loads, the actual areas between the parts in contact under these loads and the allowable stresses for these areas under fretting, sliding and fatigue conditions. The primary reduction has been achieved by removal of the Stellite from radial keys and clevis inserts on the lower support plate. Operating experience has shown negligible wear to these components and the contribution to corrosion products within the primary coolant will therefore be relatively low. The UK- EPR^{TM} has a significantly higher Stellite content within the MCPs when compared to the KONVOI design. However, no further saving in the Co-60 contribution to the radiation field was noted within the KONVOI designs when Stellite was removed from the MCPs after it was minimised within the RPV areas; the potential for further reduction of Stellite in the MCPs is believed to be low. Furthermore, no alternative to the Stellite-12 has been tested for the MCP UK- EPR^{TM} design to demonstrate suitable operation of the auxiliary hydrodynamic bearing in accident conditions.

- Valves - Stellite material is retained only within the severe accident safety valves and within the pilot valves of the safety relief valves (SRVs, commonly called pressuriser safety valves). The severe accident safety valves are not actuated during normal operation and therefore do not contribute to the activated corrosion products. In all remaining valves, the Stellite has been replaced with an iron based hard wearing material. The Stellite content within the valves has been substantially reduced, and is significantly lower than that of KONVOI and N4 designs. The contribution from the valves is <1% of the total Stellite surface area within the UK-EPRTM and so further reductions will have little effect on activated corrosion products, given the frequency of actuation and flow path of the primary coolant.

222. The report concluded that the Stellite content of components in contact with primary coolant has been optimised and no further reductions can be justified on the basis that further saving would be very small and the alternatives would require extensive qualification, which means the costs outweigh any benefits of reduced discharges and waste arisings.

f) Evidence 23: Selection of other materials to prevent corrosion

223. The design of the UK EPR^{TM} has sought to replace relevant reactor components such as seals, rotor stops and bearings that may result in the generation of corrosion products. This contributes to minimisation of sources

of radioactivity that could give rise to isotopes such as silver-110m, antimony-124, antimony-122 in the coolant; by the reduction in the use of helicoflex seals in favour of graphite seals and greater use of rotor stops and bearings without antimony. Antimony may also be present in secondary neutron sources. The impact of cladding defects of the secondary neutron source rods are limited by appropriate design [Argument 7].

224. Silver is a neutron absorber commonly used in control rods. Cladding defects in these rods are avoided by applying nitride coating on the rods. Experience from French NPPs confirms that nitrite rods show no perforation through their operating life. Therefore, these are not regarded as potential sources of contamination [Ref 37]. Nitride coated control rods will be used in the UK EPR^{TM}.

225. Owing to their general corrosion resistance and ease of working, austenitic stainless steels were chosen for most PWRs for the manufacture of large components (i.e. tubing, pump and valve casings, and reactor internals) or for cladding of the low alloy steels used in major components in areas in contact with the primary coolant [Ref 37].

226. The AREVA report on reduction of primary circuit activity based upon primary circuit materials [Ref 37] outlined the approach for ensuring usage of materials containing silver or antimony is minimised. The use of these elements is admitted provided that there is no substitute and that the use is temporary and controlled. When these elements are used measures are taken on a case by case basis to ensure that primary coolant activity is reduced SFAIRP.

227. The Baseline Environmental Summary for the 2/9RPE [Ref 215] confirmed that RPE equipment is mainly constructed from stainless steel and the components in contact with the effluent are made from stainless steel. This material choice also minimises secondary waste from maintenance and clean up avoids unnecessary early scrappage and replacement.

g) Evidence 24: Selection of materials for the secondary circuit

228. Minimising corrosion of SG tubing in the secondary circuit is an important aspect of reactor operation as it minimises the risk of the transfer of radioactive substances from the primary to the secondary system through corrosion-induced faults (e.g. cracks) through both normal and accident conditions. The radionuclides that could be transferred include fission and activation products, tritium and carbon-14 in liquid and particulate forms. Control of the chemistry of the secondary circuit to minimise corrosion risk is discussed under Sub Argument 6 ‘Control of Coolant Chemistry to ensure integrity of the secondary circuit’.

229. With respect to the selection of materials for the secondary circuit components there are two fundamental design choices for the secondary cooling system:

- the absence of copper materials; and
- the use of low chromium steel for elements that are highly sensitive to the flow accelerated corrosion phenomenon (diphasic water/steam medium).

230. Copper alloys are known to be susceptible to corrosion in the presence of ammonia or amines and ferrous materials are known to be more susceptible to corrosion in the presence of copper corrosion products. Hence, the absence of copper materials in the UK EPR^{TM} units at SZC will be of benefit in minimising corrosion in the secondary coolant system. The use of stainless steel for elements sensitive to flow accelerated corrosion is recognised as good practice and is standard practice for PWR SG tubes [Ref 41].

231. BAT assessments were conducted [Ref 42] [Ref 43] [Ref 44] [Ref 45] to examine a series of design changes to the SGs based on OEF from manufacturing for Flamanvile 3 (FA3) and other EPR^{TM}’s. This series of BAT assessments covered the following changes to the design:

- Change to the SG tube bundles tube support plates tie-rods. [Ref 42] amended the design from 44 small tie-rods to 16 larger tie-rods based on OEF from manufacture at FA3 which suggested several drawbacks associated with a large number of small tie-rods.

- Changes to the design of the SG tube bundle wrapper support [Ref 43] on the cold leg side to replace the multi-pieces' system welded onto the bundle wrapper inside the SG with a clamp adjusted in a one-piece mono-block support welded to the bundle wrapper. The design change ensured that the manufacturing process for the SG presented less risk to workers and reduced the time and cost of installation.
- Modification to the SG tube support plates broaching profile to mitigate low/moderate margins on mechanical integrity during accident conditions and prevent unnecessary manufacturing non-conformances associated with restrictive tolerances on ligaments.
- Minor modification to reduce the amount of machine work on the SG high shell forgings as the work was time consuming and added no additional benefit.

232. It was concluded for each of the design changes that they resulted in no additional resultant radioactive wastes generated, and at worst a negligible impact on decommissioning wastes associated with increased material usage. The conclusion was that there was no additional impact to the environment.

h) Evidence 25: Pre-conditioning components

233. The nature of primary component surfaces affects the ability of the passive oxides that form on them to incorporate the activated corrosion products, primarily Cobalt-60 and Cobalt-58, that are mainly responsible for occupational radiation exposure. Pre-conditioning of the surfaces of replacement components can significantly reduce contamination rates, as well as reduce the cobalt release rate. Surface treatment (roughness, chemistry, and even residual stresses) play a role in determining the amount of activity pickup. It was recognised early that EP might lower cobalt activity pickup simply by reducing the total surface area in contact with the primary coolant. Another approach in reducing the build-up of radioactivity is to effectively film or coat components that contact the primary coolant. Such coatings could serve two main functions:

- they form a diffusion barrier against the outward migration of nickel (one of the major components of 690 alloy, activated to cobalt-58) and cobalt-59 that is present as an impurity in reactor construction materials, which is desired because the release to the coolant is the first step leading to its activation; and
- coatings may render the surface less susceptible to the incorporation of radioisotopes following their formation in the reactor core" [Ref 35].

234. *"The two most widely used surface modification techniques now used in US nuclear power plants are electro polishing (EP) and a chromium coating and passivation technique that is designated the 'Stabilized Chromium Process' (SCrP)"* [Ref 35]. Passivation of the RCP surfaces during hot functional testing [Evidence 34] has a significant impact on minimisation of corrosion product release [Ref 37].

235. It was estimated for the UK EPR^{TM}, using operational feedback from 1,300MWe French units as well as other international data, that treating the SGs channel heads by EP may reduce the equivalent doses by 40% in the zones treated. This would imply an improvement on the annual collective dose of around 10 man mSv, equivalent to an overall 3 % decrease on the collective dose. (The collective dose values cited refer to exposure to workers.)

236. Further to this, 'The Use of BAT to Minimise Production of Activated Corrosion Products Considering Improvements From GDA' [Ref 36] determined that EP of the steam-generator heads, which is primarily undertaken to minimise worker dose, does have the benefit of reducing deposition of radioactive material in

the SG heads (that could lead to increased discharges). Therefore, it is BAT for EP to be used on SG heads for the UK EPR[TM] at SZC to minimise both worker dose and discharges to the environment.

i) Evidence 26: Specification of materials to prevent movement of corrosion products

237. Ensuring that the primary coolant system is leak tight and protected against corrosion will limit the activity which leaves the system and therefore requires further treatment prior to discharge. Materials can be specified to reduce the risk of leakage, this is discussed further under Claim 2, Argument 9. Active parts on the system (pumps and valves) are particularly susceptible to leaks and will therefore be targeted. Pumps in the REA are of the canned rotor type to reduce the risk of leaks [Ref 40].

j) Evidence 27: The specification of materials for the procurement of the SG and RPV to minimise corrosion

238. UK contract A CSCT ECUK09010 rev C [Ref 46] has specified restrictions on the residual elements of the SG and RPV forgings, in order to minimize cobalt release in the primary coolant and consequently the activity of corrosion products. The specification for the UK procurement of SG and RPV forgings states that the residual elements shall be restricted as follows:

- phosphorus content less than or equal to 0.006% for RPV core area;
- copper content less than or equal to 0.06% for RPV core area, 0.1% for other RPV forgings;
- vanadium content less than or equal to 0.01% for RPV core area, other RPV forgings and S forgings; and
- cobalt content shall be a maximum of 0.02% in RPV core shells (0.03% on FA3, cf RT M2111).

The following residual elements target values for RPV and SG forgings:

- arsenic less than or equal to 0.02%
- antimony less than or equal to 0.01%; and
- tin less than or equal to 0.05%.

239. The SG tubing represents over 85% of the wetted circuit (i.e. the surface area within the primary circuit that is in direct contact with the coolant). The SG tubes therefore represent the principal source of corrosion products produced during normal operation. Improved corrosion resistance of the SG tubing significantly reduces the corrosion product release rate, in turn reducing worker dose, waste activity and dose to the public.

240. ‘The Use of BAT to Minimise Production of Activated Corrosion Products Considering Improvements from GDA’ [Ref 36] sets out a number of considerations to assure that the design and manufacture of the SG tubes represents BAT:

- The SG tubes are manufactured from Alloy690TT which undergoes additional thermal treatment after the final mill anneal stage, to relieve fabrication stresses and improve the microstructure. This is undertaken twice at the U-bends. Increased chromium content results in improved corrosion resistance compared to other allows typically used for SG tubes manufacture.
- The specification for each cast of Alloy690TT which is used to produce the SG tubes is ≤0.035% Co. The weighted average per tube bundle however is specified to be much lower at ≤0.015% Co. This is broadly consistent with that specified in recognised best practice standard (The RCC-M standard recommends ≤0.018%, whilst EPRI recommends ≤0.015%.). The specification used in Sizewell B (one of the best performing stations as reported by World Association of Nuclear Operators (WANO)) was also ≤0.015% weighted average per tube bundle [Ref 34]. It was concluded that a

reduction in the limit to 0.014% would have a negligible impact on corrosion, especially considering that these represent upper limits for Cobalt content, and 'typical chemistries' achieved for EPR^{TM} SG tubing would be below the EPRI recommendation.

- Control of these residual elements relevant to corrosion in Alloy690TT for the SG tubing is follow the recommendations of RCC-M 4105, the recognised code representing RGP as demonstrated in [Ref 36]. It was assessed whether it would be BAT to align permitted copper and sulphur concentrations with lower EPRI recommendations, however it was concluded that this would have a negligible effect on corrosion.
- The manufacturing process follows the RCC-M 4105 AFCEN standard which specifies steps in the manufacturing process pertinent to corrosion resistance. The manufacturer will be required provide evidence of QA & acceptance testing which assesses the internal surface of the manufactured SG tubes against reference tubes.
- Passivation of the SG tubes is planned as it can significantly reduce contamination release rates and cobalt release rates. This will take place during hot functional testing in the commissioning phase.

6.1.5 Claim 1, Argument 5: Management of Primary Coolant Chemistry to Minimise Generation of Radioactive Waste

241. Radiological protection standards for workers, waste management requirements and the ability to undertake maintenance and operate the reactor in a safe and efficient manner require the radioactive source term to be minimised. The achievement of optimised primary circuit chemistry is one of the fundamental operational objectives associated with minimising the production of activated corrosion products at source.

242. The selected chemistry regime for the UK EPR^{TM} units at SZC balances the conflicting requirements for maximising fuel performance, fuel-clad integrity and primary circuit pressure boundary integrity as key elements of the NSSS, whilst minimising worker doses and radioactive waste generation. The control of primary coolant chemistry is achieved using a number of systems, primarily the RCV, REA and the Nuclear Island Sampling System (REN). Correct primary coolant chemistry specification and control is fundamental to the minimisation at source of radioactive waste for a PWR because of the following aspects:

- Contribution to maintaining the integrity of fuel element cladding: so that almost all the radioactive substances produced in the fuel (representing > 99 % of the total reactor source term) are retained in the spent fuel during use, handling, storage, packaging and transport for off-site management [Evidence 27];
- Contribution to maintaining the integrity of the primary circuit pressure vessel by minimisation of corrosion: thereby minimising the risk of primary coolant leakage from the circuit, which avoids the generation of waste from effluent treatment and the disposal of redundant components [Evidence 28];
- Minimise the production of tritium: by optimisation of the gadolinium load [Evidence 8] and the use of enriched boric acid in conjunction with depleted lithium hydroxide for primary coolant pH control [Evidence 31];
- Control of the concentration of dissolved gases and impurities that generate radioactivity through neutron activation, in particular carbon-14 and tritium [Evidence 32];
- Minimisation of secondary waste arisings:

- it minimises the treatment requirements for primary coolant and subsequent generation of secondary wastes, principally, ILW spent filters and resin media;

- it minimises solid waste generation from the treatment of liquid and gaseous effluents that are generated during the management of primary coolant, reactor off-gas and spent fuel; and

- it minimises solid waste generation arising from various decontamination processes due to the deposition of corrosion products on reactor circuit and fuel element surfaces [Evidence 33].

243. The primary coolant chemistry specification used on any PWR can be modified at any stage during the lifecycle of the reactor in response to OEF, which may reduce the radioactive source term and consequential waste arisings. Any modifications to primary coolant chemistry that results in increased discharges would require justification as being BAT.

244. The primary coolant chemistry specification for the UK EPR^{TM}, as proposed for the GDA, can be considered as optimised, evolving from decades of PWR OEF in France, Germany and internationally. Many PWRs have operated safely during their anticipated operational lifetimes (and during subsequent extensions) whilst producing minimal radioactive wastes and having a low environmental impact using similar primary coolant chemistry and control specifications. The UK EPR^{TM} specifications are consistent with guidelines and recommendations published by EPRI, which have been developed by the major international PWR operators and designers. EDF will continue to keep abreast of developments as part of its OEF processes and as a member of organisations such as WANO, Institute of Nuclear Power Operations, EPRI and IAEA.

245. The UK EPR^{TM} design benefits from considerable experience of applying various primary coolant chemistry regimes to identify those which offer the optimal performance for a wide range of competing requirements including safety, radiological protection, environment and commercial constraints. The primary coolant chemistry specification and control regime presented for UK EPR^{TM} can therefore be considered as currently representing BAT.

246. The final primary coolant chemistry specification for SZC has not yet been agreed, and the GDA provides the baseline data and specification for discharge and disposal assessment purposes. This is covered by [SZC RSR CMT7] of the forward work plan contained in the permit application head document [Ref 1].

247. Implementation of the primary coolant requirements for the UK EPR^{TM} at SZC will require compliance with plant operating instructions and technical specifications, whose requirements will vary depending on reactor operating conditions. Personnel responsible for these activities will be suitably qualified and experienced to ensure that requirements are effectively implemented and minimisation of radioactive waste at source is achieved.

248. A number of actions will need to be taken in relation to primary coolant chemistry as the development of SZC progresses. These include the design of and management arrangements for the engineering systems and automatic control systems. An important example of these is the REN which enables the monitoring and optimisation of primary coolant chemistry. Other actions cover the specification of coolant composition and the systems and management arrangements for the use of enriched boron. The inclusion of the specification of primary coolant chemistry will enable the consideration of best practice that emerges from EDF and international OEF before the start of reactor operations and which can thus be used to inform the decisions on coolant composition at the appropriate stage of development.

a) Evidence 28: Contribution to Maintaining Fuel Element Cladding Integrity

249. Evidence 1 describes the selection of the Zircaloy-M5 material for the fuel cladding for the UK EPR™. It also describes the performance and ability of the cladding to retain the radioactivity produced in the fuel element and its compatibility with the proposed chemistry specifications for the primary coolant and spent fuel storage pools for the UK EPR™. The use of Zircaloy M5 cladding material (with low corrosion) will allow the higher lithium concentration in the primary coolant that is necessary to achieve the optimal pH required by the use of high burn-up fuel in the UK EPR™ [Ref 37]. The dry storage casks are filled with inert helium and rigorously dried to remove any mechanism for degradation that would lead to a fuel cladding failure once in storage [Ref 32]. Further information on the fuel manufacturing process is presented in Evidence 9.

b) Evidence 29: Contribution to the Minimisation of Corrosion Products

250. The UK EPR™ has optimised the following aspects of primary coolant chemistry to minimise corrosion products:

- maintaining a constant pH value in the primary coolant by optimised regulation of the lithium concentration;
- controlling the concentration of dissolved hydrogen in the primary coolant so as to reduce the oxygen content and limit radiolysis of water;
- better elimination of the dissolved oxygen during boron recycling, by evaporation and degassing, and recombination of the hydrogen in the gaseous effluent treatment system; and,
- zinc will be injected into the RCV in the form of zinc acetate solution, to reduce the generation of corrosion products and to prevent the incorporation of cobalt in the oxides from zones outside the flux [Ref 16]. A BAT justification is provided in the GDA PCER [Ref 47].

251. The UK EPR™ incorporates design improvements that aim to reduce the production of liquid chemical and radioactive effluent at source, in particular:

- Among options for various coolant pH control (co-ordinating boron and lithium), the choice of constant pH at 300°C has been achieved in any fuel cycle scenario. This pH regime ensures minimisation of corrosion and build-up of “crud” in the reactor core (wherein formation of activation products takes place) and control over the transport of the activated material out of the core and into other downstream systems. The principle of boron-lithium coordination is to maintain a constant pH in the primary circuit which ensures a positive temperature coefficient of corrosion product solubility in the core region. As the temperature of the primary coolant increases in the core region, deposition of corrosion products in that region will be minimised by a positive temperature coefficient of solubility. Therefore, the formation and deposition of activated corrosion products will be minimised in out-of-core regions.
- Best available demineralised water ensures integrity of all primary (and secondary) circuit structural components (e.g. avoidance of stress corrosion cracking) and avoids build-up of silica deposits on fuel rods (that can allow formation of zeolites). It also minimises the requirements for let-down of coolant from the primary circuit and other systems due to impurity levels rising above those given in the relevant reactor coolant specifications (such as silica, sulphate, chloride).

252. The chemistry regime currently selected for the UK EPR™ is consistent with recommendations developed by EPRI, which are considered by relevant EDF technical working groups responsible for the revision of EDF standards and is considered to represent international best practice. An evolutionary approach to integrating

chemistry into the UK EPR^{TM} design has been adopted. It is known as: Chemical and Radiochemical EPR^{TM} Design Optimisation (CREDO), and is mainly based on:

- Critical and objective examination of French, German and international operating feedback, concurrent with a comprehensive analysis to identify and appraise the significant parameters, with a view to taking them into account from the design stage onwards. One of the main aims of CREDO in this respect will be to limit the number of chemical and radiochemical specifications to those strictly required to operate the UK EPR^{TM}, and thereby to determine the BAT to be implemented.

253. It would be premature to indicate the final values of the chemical parameters that will be adopted, at the current stage of the project. Nevertheless, the main features have already been made: they are described in the following paragraphs.

254. The following topics are split into 3 items in order to explain how the CREDO approach is used on the UK EPR^{TM} design for minimising the source term during all periods of operation at power, shutdown and start-up:

- Power operation:
    - primary coolant pH management;
    - zinc injection;
    - dissolved hydrogen control; and,
    - secondary system chemistry;
- Shutdown; and,
- Start-up.

255. For the demonstration of BAT presented herein, only information on primary coolant pH management for reactor power operation, zinc injection and reactor start-up and shutdown phases is presented below. These requirements are based on OEF of the French PWR fleet and input from CREDO, as outlined above. A final decision on the requirement for dissolved hydrogen control has not yet been made for SZC.

256. There is little data on the effects of hydrogen concentration on radioactive contamination in PWR RCP. Main known investigations and results come from Tsuruga (Japan) and Beznau (Switzerland). Both experiences seem to support the need for decreasing hydrogen concentration. Crud inventory on fuel surfaces and deposited activities on RCP surfaces decrease with hydrogen concentration. This is attributed to the stability of nickel oxide/nickel. Theoretical calculations based on thermodynamics data of the transition between nickel and nickel oxide demonstrates a low concentration of hydrogen at the core inlet is needed to limit formation and deposition of metallic nickel.

257. Preventive zinc injection aims to minimise residual contamination by the radio-cobalt's in the out of core areas. The use of zinc injection in the UK EPR^{TM} is expected to lead to dose rate reductions of about 10 - 15 %. In all the reactor units using zinc injection, a dose rate reduction has been detected after a certain period of exposure without any subsequent negative effects on plant systems, components and operation. Furthermore, zinc injection is a primary coolant strategy which is beneficial with respect to minimising fuel crud deposition and improving material performance. Nowadays, all PWRs can, using chemical specifications, implement zinc addition in the most economical manner and without unexpected adverse effects on the fuel, waste and effluents. Zinc injection will be performed for the UK EPR^{TM}. Taking into account the extensive PWR feedback and the large amount of work that has been carried out by the international community to optimise zinc injection, the UK EPR^{TM} can benefit from the positive effects of zinc injection from the first cycle of operation.

Not only should an optimised pH 300°C be targeted, but it should also be constant from the start of and for the duration of the fuel cycle. A pH value of 7.2 has been adopted at the current stage of the studies, in the light of the positive operating feedback from the French PWR fleet.

258. At the beginning of life, the boron-10 enriched boric acid will have to be used with sufficient increase in lithium (CLi) concentration to obtain this pH value. Thus, the permissible maximum lithium concentration has been determined and set at, for example, 4 mg kg-1 for UK EPR^{TM}. This is considered compatible:

- with the corrosion resistance of the fuel cladding (M5^{TM} alloy), regardless of the core management adopted; and,
- with materials in contact with the primary coolant.

259. The target isotopic enrichment in boron-10 proposed for the enriched boric acid will be 37 atom % [Ref 48]. This value corresponds to a design choice that accommodates all the fuel management options, provides the anti-reactivity margins required for the safeguard systems, in addition to the nuclear auxiliaries and meets the environmental requirements for boron releases.

260. On the basis of the operating feedback from various countries and theoretical studies on corrosion products behaviour the recommended cold shutdown procedure following hot shutdown provides for:

- the reduction in hydrogen content;
- the removal of lithium from the primary coolant to decrease pH;
- elimination of fission products from primary coolant (in case of fuel fail);
- forced oxygenation of the primary coolant by injecting hydrogen peroxide (sustained with air injection); and,
- starting the highest purification flow rate as early as possible. The RCV let-down flow on UK EPR^{TM} has been considerably increased for this purpose, in relation to the existing French power plant units, flow at 72 te h^{-1}, thus doubling purification capacity.

261. Premature RCP oxygenation, during the Hot Shutdown Mode, (in particular in the Pressurizer (PZR) whose temperature is still ~250°C in order to maintain a pressure above 25 bar) can have an unfavourable impact in terms of stress corrosion cracking and in terms of activated corrosion product release and transport on the RCP (especially at the RIS/RA connection point). To prevent the corrosion risk, the decision was made to inject hydrazine directly in the RCP using the RCV. This injection takes place prior to the connection of RIS-RRA trains (From ~120°C to 80°C) during the plant shutdown phase as during this period there is an increased risk of corrosion to the RCP and the PZR and potentially subsequent recontamination via corrosion product transport. [Ref 49].

262. As regards post-refuelling start-up, chemical treatment avoids corrosion risks and also limits the corrosion products source term, primarily by efficiently removing the released nickel from primary coolant.

263. During plant start-up, the following main operating phases are envisaged to do this:

- static and dynamic venting;
- starting the online degasser as early as possible at the maximum flow rate on the RCV, to reduce the dissolved oxygen concentration;
- setting the purification unit on the RCV to remove the residual corrosion products at low temperature. The nickel concentration reduction target should aim for below 100 – 150 µg kg^{-1}, provided the primary coolant temperature has not reached 120°C;

- hydrazine injection from 80°C to remove the residual oxygen, to achieve a criterion of O2 < 100 µg kg^{-1};
- Total boron concentration: value required by fuel management to manage criticality; and,
- The hydrogen and lithium hydroxide will be injected into the primary coolant when the reactor has reached the hot shutdown state.

264. As outlined above lithium usage has been optimised for the UK EPR™ to minimise corrosion products as part of controlling primary coolant pH.

c) Evidence 30: Zinc injection to manage corrosion

265. When zinc is added to the coolant water in a PWR it affects the production and distribution of activated corrosion products in a number of complex and inter-related ways. Two effects in particular explain why zinc injection is effective in reducing worker radiation doses: it reduces the rate of corrosion of the metal surfaces in contact with coolant water and it inhibits the re-deposition of activated corrosion products in out-of-core regions of the primary circuit. In addition, the zinc diffusion into the inner oxide layers contributes to prevent the initiation of Stress Corrosion Cracking

266. Zinc injected into the coolant water of a PWR becomes incorporated into the oxide films on the surfaces of the metallic components that are in contact with the coolant, making the films thinner but more protective than they would be in the absence of zinc. The result is a reduction in the rates of corrosion and total release of material from the components into the coolant water. Fewer corrosion and erosion products released into the coolant means less creation of radioactive isotopes by neutron activation of the corrosion and erosion products in the reactor core, which in turn means that there are fewer activated corrosion products available to redeposit in out-of-core regions of the primary circuit where they can result in worker doses. The results of laboratory and in-reactor experiments confirm that zinc addition reduces the rates of corrosion and total release of material from stainless steel, Inconel and Stellite.

267. The incorporation of zinc into the oxide films on the surfaces of the metallic components in contact with the coolant water in a PWR occurs in preference to the incorporation of radioactive isotopes of other metals (most importantly, cobalt) into the films.

268. The effectiveness of zinc injection for a new reactor in reducing worker radiation doses is demonstrated by operational experience and experience from the Angra-2 PWR in Brazil, which has performed zinc injection from the start of operation, as is proposed for SZC. Much more evidence of the effectiveness of zinc injection can be found in operational experience from the many PWRs (around 60 at the end of 2010) that have commenced zinc injection after some considerable period of prior operation. As for any other approach, the benefits obtained from zinc injection in each unit are difficult to extrapolate to other units due to the influence of several design factors and operating conditions. However, the available feedback provides a realistic estimation of the potential benefits from zinc. For instance, Angra-2 PWR is a Siemens-designed 1,300 MW(e) PWR that started operation in 2000. The plant is closely comparable to other Siemens reactors of the same basic design that started operation, without performing zinc injection, in the 1980s in Europe. Dose rates measured at locations in the primary circuit of the Angra-2 reactor are at least three times lower than the corresponding dose rates at Siemens reactors of comparable design that have not performed zinc injection. This provides confidence that zinc injection will be effective in reducing worker radiation doses at SZC from the outset.

269. Although environmental benefit has not been a motivating factor in operators choosing to adopt zinc injection, some attention has been given to the environmental effects of zinc injection and, while there has been no attempt to precisely quantify and weigh the environmental advantages and disadvantages of zinc injection,

there is evidence that the net environmental effect is small and trivial in comparison to the principal advantage of reducing worker radiation doses. It is considered that there is a potential for positive impact on the environment is expected due to the reduction of the source term and the consequent potential activity decrease in waste and liquid discharges [Ref 50].

270. The possible environmental effects of zinc injection are several and may be either beneficial or detrimental. An obvious possible environmental benefit is the previously discussed reduction in the production of activated corrosion products, which might result in reduced discharges of radioactivity in liquid effluents and reduced accumulations of radioactivity in solid wastes. Counter-balancing this effect is the fact that the injection of zinc results in the creation of additional radioactivity in the form of the radioactive isotope zinc-65. At SZC, zinc depleted in the stable isotope zinc 64, which is the precursor of zinc-65, will be used. Thus, the production of zinc-65 is less of a concern. A possible environmental detriment that is perhaps less obvious is the possibility that the capture of zinc by the ion exchange resins that purify the coolant water could result in the resins being exhausted more quickly, causing an increase in the volume of radioactive waste generated.

271. To attempt to precisely quantify and balance these, and any other, environmental benefits and detriments of zinc injection would be a difficult and time-consuming task. However, OEF suggests that the effects of zinc injection on liquid discharges and solid wastes are so small that such an attempt is unnecessary. When zinc injection was started at two of the PWRs at Bugey in France, there was no detectable effect on the concentration and isotopic distribution of the radioactivity in discharged liquid effluent, no detectable increase in the volume of solid wastes created (resins, filters and concentrates), and no great change in the concentration and isotopic distribution of radioactivity in the solid wastes. Similar findings have been reported when zinc injection was started at PWRs in Germany, USA, Japan, and Spain [Ref 51].

272. There is some uncertainty associated with the speciation of carbon-14 following the injection of depleted zinc in an acetate form. This may affect the partitioning of carbon-14 between environmental media. Analysis carried out by EDF shows that the production of carbon-14 from acetate is completely negligible compared with the overall carbon-14 production from the other sources. Acetate is an organic molecule which is decomposed in the primary coolant in a short time due to the temperature effect and neutron/gamma flux environment of the RCP. Therefore, no negative impact is expected. In the event that the acetate remains in the RCP and reaches the RCV, it will decompose at low temperature into CO2 and HCO3-. The CO2 will then be removed by degassing in the Volume Control Tank (VCT) and the bicarbonate will be retained by anion resins. Therefore, under this hypothetical condition the speciation distribution of carbon-14 should not be affected.

273. In summary, there can be a high degree of confidence that using zinc injection at SZC will be effective in achieving the principal aim of reducing worker radiation doses. Operational experience of zinc injection in PWRs suggests that the effects on discharges and solid wastes are so small as to be trivial in comparison with the safety benefits gained.

274. The full Claims-Arguments-Evidence presented in in favour of implementation of zinc injection on the SZC project are contained within [Ref 52] & [Ref 53].

d) Evidence 31: Automatic Control of Primary Coolant pH

275. It is anticipated that an automatic control system will ensure that the primary coolant pH is maintained. Automatic control will ensure that the optimum chemistry for minimising the production of corrosion products is maintained at all stages of reactor operation for which primary coolant temperature and pressure are important parameters.

276. It is also useful to have means to enable a constant pH300°C to be maintained throughout the cycle in addition to the intrinsic pH300°C [value defined in Evidence 27]. This function will be provided at all times, using an automatic lithium hydroxide injection device. Its function will be to offset all lithium concentration variations

of the primary coolant in real time, by injecting lithium hydroxide in aqueous solution. This device is controlled by a feedback control driven system, by comparison with online boron concentration and lithium concentration measurements in the primary coolant (measurements are obtained by the REN). An analogous prototype device has been installed at French Tricastin unit 2 NPP, where it has been running for several cycles. It effectively counteracts load follow effects and consequently observes the target pH300°C set point for the coolant.

277. Use of high burn-up fuel in the UK EPR^{TM} will require higher levels of boron and hence lithium in the primary coolant at the start of each cycle. This could contradict operating at a constant pH300°C. However, this is balanced by the use of enriched boron. It has been decided that the "APC" or Advanced pH concept shall be implemented [Ref 54]. This allows lithium recovery from the RCV fluid for the re-use of Lithium and the removal of any excess lithium in the primary coolant.

278. For the UK EPR^{TM} a reduction in primary circuit radioactivity, SFAIRP is achieved by use of high Li concentrations. A maximum Li concentration of 4 mg/kg allows the pH300°C target value to be reached, which leads to a minimization of corrosion products in the primary coolant. Experimental programme and operational experience bring evidence that no drawbacks with regard to material behaviour have been reported for such Li concentrations [Ref 37].

e) Evidence 32: Minimisation of production of Tritium

279. The primary coolant is treated with boric acid for its neutron absorbing properties, which can be recovered and recycled through evaporation of primary coolant in the UK EPR^{TM} boron recycling system. Boric acid is enriched with boron-10 isotope in order to reduce the total amount of boric acid required in the system as this has a much higher neutron capture cross section than boron-11. In turn, this reduces the amount of lithium required in order to offset the acidity of the boric acid, preventing equipment corrosion. The use of enriched boric acid is anticipated for SZC but this requires the use of an evaporator to enable the recycling of enriched boric acid. The use of boric acid enriched with boron-10 significantly reduces generation of tritium in normal circumstances [Ref 5].

280. The primary circuit is treated with:

- Boric acid, because of its neutron-absorbing properties: the proposed treatment of the primary water facilitates greater recycling. The use of boric acid enriched with boron-10 significantly reduces discharge in normal circumstances.
- The level of lithium required is a function of the concentration of boron in the primary coolant. The approach adopted for the UK EPR^{TM} is to enrich the boric acid so that the equivalent boron-10 level, needed for reactivity control, is 30 - 40 % of the boron, as opposed to the natural level of 20 %. 37% enriched boron-10 boric acid at a concentration of 4% (i.e. 7000 ppm of boron) will be used. This has the effect of reducing the level of boron, and hence lithium, in the coolant [Ref 48]. Optimal pH control by boron-lithium coordination ensures the integrity of primary circuit components (corrosion etc.) including SG tubes, but at the same time avoids higher concentrations of Li that could act as a significant source of tritium (or give rise to other operational problems).
- At the expected lithium concentrations in the primary coolant (a few ppm), with natural lithium, tritium production would be approximately 1-2 TBq per day. This would clearly lead to very large arisings of tritium. It was decided, therefore, at an early stage in PWR design to deplete the lithium-6 in the injected lithium to reduce tritium discharges. This is an inherent design feature, but is also an important source minimisation technique. The specification for the UK EPR^{TM} is that lithium-6 in injected lithium should not exceed 0.1 %. Use of lithium hydroxide containing more than 99.9 atom % lithium-7 minimises the production of tritium from the lithium-6.

281. To offset the drop in the pH at 300°C due to an increase in the boron concentration inherent in the UK EPR^{TM} fuel cycle of at least 18 months, a lithium concentration of 6 ppm at the beginning of fuel life is envisaged by applying boron-lithium ratios. Three boron-lithium ratios are being studied to evaluate the tritium source term, for UK EPR^{TM} fuel management options:

- ‘Low lithium’ chemistry: a “Top of operating range” maximum lithium concentration fixed at 2.2 ppm of lithium at the start of the fuel cycle (maximum lithium concentration currently recommended), then linear decay to 0.6 ppm from a boron concentration of 560 ppm.";
- ‘High lithium’ chemistry: a “Top of operating range” maximum lithium concentration fixed at 3.5 ppm of lithium at the start of the fuel cycle, then linear decay to 0.6 ppm from a boron concentration of 860 ppm. It is different from “DUO” chemistry in that there is only one step at 3.5 ppm of lithium, followed by a linear decrease. High lithium chemistry is not applied to current management options in use; and,
- A boron-lithium ratio with constant pH 300°C, with a maximum lithium concentration which may reach 6 ppm at the start of the fuel cycle.

282. “Top of operating range” chemistry means that the maximum lithium concentration values specified are assumed.

283. Other ways of reducing tritium production include the use of highly depleted lithium hydroxide (99.99 % lithium-7). The pH compensation would then use less lithium (approximately 4 ppm) and may reduce further the production of tritium.

284. The final specification for boron/lithium chemistry in the UK EPR^{TM} has not yet been made due to ongoing optimisation studies. The final specification will be provided in due course. Importantly, the system is designed to enable optimisation of primary coolant chemistry.

285. The gadolinium load is increased and optimised in the UK EPR^{TM} in order to reduce the boron concentration in the primary coolant and hence the tritium production, while controlling consequent losses of EFPD [Ref 55]. To enable better control of the boronation of the primary circuit, improvements have been made to various pieces of I&C of the REA, based on tests using the Phase 3 UK EPR^{TM} simulator, and provision has been made for local control for boron solution mixer in REA, allowing automatic control [Ref 56].

f) Evidence 33: Control of gases in the Primary Coolant

286. The concentration of hydrogen, nitrogen and oxygen gases in primary coolant must be controlled with compliance of the selected primary coolant chemistry specification. Nitrogen and oxygen impurities are associated with the production of carbon-14, and oxygen also contributes to in-circuit material corrosion, which must be minimised. Hydrogen is required to control corrosion rates, as described below, but it presents a conventional safety hazard and its concentration must not exceed certain values.

287. The chemical environment of a primary PWR is reducing and the concentrations of dissolved hydrogen are sufficiently high to consume radiolytically generated oxygen species and therefore diminish corrosion effects [Ref 5].

288. The concentration of radioactive noble gases and tritium in primary coolant require control for the radiological protection of workers. This is achieved by the degassing and let-down of primary coolant. These processes minimise the potential for accumulation in the nuclear island buildings as a result of diffusion and leakage of noble gases and tritium from primarily coolant chemical processing systems. However, these radiological protection requirements result in increased radioactive discharges. The impact of these discharges is low compared to the worker dose reductions and operational advantages of easier plant access due to reduced

airborne radioactivity levels. Therefore, on balance the trade-off between the increase in discharges and operational advantages, including reducing worker dose, it is considered to be the optimum approach.

289. The UK EPR™ uses nitrogen gas to control the pressure in the VCT and also uses it as a purge and sweeping gas, as introduced above. Under these conditions, and upon addition of make-up water, dissolved nitrogen will be present in the coolant, the concentration of which depends upon the partial pressure in the system. The use of nitrogen is based on evolution of the PWR design, taking account of the OEF from the KONVOI reactors in Germany, which use nitrogen instead of hydrogen. This change reduces the non-radiological risks associated with the storage of large volumes of hydrogen, thereby enabling a reduction of the volume of stored hydrogen of 1,000 m^3. No formal options assessment has been carried out and its inclusion in the UK EPR™ design is based on benchmarking against world practice in PWR design and operations, as part of the UK EPR™ environment design review, and review of non-radiological safety issues.

290. The use of nitrogen as a cover gas is considered to be the BAT for the UK EPR™ for the flushing of components in the primary circuit, despite the modest addition to carbon-14 discharges that the change introduces (in comparison with other PWRs). Flushing of the system is necessary to achieve coolant degasification and also limits the hydrogen content in the system and connected components to less than 4 % (the Lower Explosive Limit for hydrogen) by volume. It may be noted that the oxygen content is also managed/limited to avoid corrosion of the primary circuit. The nitrogen concentration in the coolant is determined on the basis of measurement of temperature and pressure, taking account of the need to control the hydrogen concentration [Ref 5].

g) Evidence 34: Minimisation of secondary waste arisings

291. Use of boron-lithium co-ordination and zinc injection in the primary coolant circuit minimises the quantity of activated corrosion products formed during operation. Therefore, the level of activated corrosion products present in the TEP demineralisation media will be reduced accordingly. This will allow reduction of the activity of solid waste arisings. The volumes may not be reduced since the TEP demineralisation media will be used to control the lithium level in the primary coolant.

6.1.6 Claim 1, Argument 6: Commissioning, start up and shutdown procedures to minimise the generation of radioactive waste

292. Start-up and shutdown of the reactor increases the risk of generating corrosion products, such as iron, nickel and cobalt within the NSSS, primarily the primary circuit. There are a number of measures integrated into the UK EPR™ design which minimise the generation of corrosion products within the primary coolant circuit. Predominantly, the minimisation of corrosion product generation at source is ensured through optimisation of primary coolant chemistry and the selection of specific reactor materials and components. However, there are also a number of additional procedures which can be conducted during commissioning, start-up and shutdown which ensure that the generation of corrosion products is minimised. These UK EPR™ design features are set out in the following sub-sections:

- Commissioning – Hot functional testing of the reactor circuit components takes place during commissioning, whereby the primary circuit is chemically conditioned (alkaline and reducing conditions) at hot shutdown temperature for a prolonged period causing an oxide layer to be produced on the internal surfaces of the-circuit. This provides a tight and protective layer which will subsequently minimise the generation of activated corrosion products. Zinc injection can be considered as it can help to improve passivation. Prior to the hot functional testing, flushing of the primary circuit also occurs by purification, removing any impurities which may be present within the primary circuit [Evidence 34].

- Shutdown – A cold shutdown procedure will be carried out following hot shutdown, resulting in the forced oxygenation of the primary circuit. This procedure allows for the controlled release of corrosion products into the primary coolant from in-circuit and fuel cladding surfaces, known as a ‘crud burst’ and corrosion product ‘spiking’. Corrosion products are subsequently removed from the primary coolant under controlled conditions through liquid abatement techniques. The purification rate will be increased following the ‘crud burst’ in order to accommodate the additional corrosion products which are released, including cobalt-58, cobalt-60, manganese-54, iron-59 and chromium-51. The increased purification rate also aims at retaining high dose pollutants such as silver-110m, antimony-122 and antimony-124. This reduces dose rates, further corrosion product activation and minimises the potential for fuel cladding corrosion and consequent into the primary circuit [Evidence 35].
- Start-up – Prior to start-up following re-fuelling the primary coolant circuit must be degassed and purified to reduce impurities such as dissolved oxygen and nickel to low concentrations. This minimises the generation of corrosion products, which could subsequently become activated within the primary coolant circuit [Evidence 36].

a) Evidence 35: Commissioning procedures

293. During the plant commissioning programme, an oxide layer will be produced on reactor circuit components by exposing the material to demineralised water at high temperatures for a prolonged period in alkaline and reducing conditions. The entire primary coolant circuit will be flooded as part of the hot functional test. A detailed specification for this process is being developed to ensure that use is made of operational experience, particularly at Sizewell B and HPC.

294. Prior to the hot functional test, flushing of the primary circuit, by purification using appropriate chemistry conditions and operation of the primary coolant treatment plant (RCV), will be undertaken [Ref 5]. Moreover, taking into account the OEF from Tomari 3, zinc injection during hot functional testing can contribute to improving the passivation process.

b) Evidence 36: Shutdown procedures

295. A modified chemistry regime (reduced pH) is implemented at PWRs prior to refuelling upon shutdown, the primary purpose of which is to remove corrosion products from in-circuit and fuel cladding surfaces. This measure will also reduce worker doses. This standard practice reduces the radioactive source term by avoidance of further corrosion product activation and minimising the potential for fuel cladding corrosion and consequent leakage into the primary circuit. The main stages to achieve these objectives involve reducing pH by the removal of lithium in addition to forced oxygenation through introduction of hydrogen peroxide followed by high-flow rate decontamination in the RCV. There is an expected temporary increase in filter arisings and secondary radioactive liquid effluent arisings as a result of these activities [Ref 5].

296. During refuelling outages, the primary coolant is oxygenated by the addition of hydrogen peroxide. The chemical conditions in the primary circuit therefore change from reducing to oxidising, resulting in a phenomenon known as a “crud burst” oxygenation peak. This practice is undertaken at all PWRs.

297. The switch to oxidising conditions causes much of the oxide layer formed during operation on the out-of-core primary circuit surfaces to be stripped off and either suspended or dissolved within the reactor coolant. This causes a temporary increase in primary coolant activity and consequently, radiation dose rates around RCP components, but this is reduced rapidly by removing the “crud” in the filters and demineralisers of the RCV. Nevertheless, there is a slightly elevated activation product concentration in the reactor coolant following the crud burst, which leads to more radioactivity entering the TEU. If forced oxygenation with hydrogen peroxide

were not carried out the crud burst would still occur, but in an uncontrolled way, when the reactor pressure vessel head is removed exposing the coolant to air (and never generally undertaken in practice) [Ref 5].

298. Design change CANP0068UK will result in the installation of a diverse means of Boron dilution detection in shutdown states. The additional boron meters will be closer to the source than those already incorporated into the design, resulting in a faster detection time. A parametric study was undertaken by AREVA (now Framatome) to demonstrate that the solution would not result in spurious detection. See [Ref 57] for BAT Assessment Form justifying the design change.

c) Evidence 37: Start-up procedures

299. After refuelling, primary coolant will be degassed and purified to reduce impurities such as dissolved oxygen and nickel to low concentrations, which are specified according to requirements [Ref 5].

6.1.7 Claim 1, Argument 7: Selection of Secondary Neutron Sources to Minimise Discharges

300. Measurements of neutron flux provide information on what is happening inside the core of a nuclear reactor. This assists control of the reactor and helps to ensure that anything inadvertent that is happening inside the core is detected. Continuous measurement of neutron flux is required at all times when fuel is present in a reactor, including when the reactor is in a sub-critical condition during shutdown and start-up.

301. Practical choices of neutron source for use in a reactor are limited, and to be carefully considered given that use of certain materials can result in their activation, and therefore the generation of additional radioactivity in the primary circuit. Although the decay of some radioactive isotopes does result in the emission of a neutron, the half-lives of such isotopes are too short for them to be used to make practically useful neutron sources in the same way that useful gamma sources can be made using any one of a number of radioactive isotopes. Practically useful neutron sources are of three types: spontaneous fission sources, alpha-neutron (alpha, n) sources and photoneutron sources. There are 2 aspects to consider when selecting secondary neutron sources:

- choice of source material [Evidence 37]; and
- choice of cladding material [Evidence 38].

302. Overall, with the knowledge and experience that is available at this time, it is considered that the use of antimony-beryllium sources is currently BAT with respect to the minimisation of tritium discharges arising from the use of secondary neutron sources in the UK EPR $^{\mathrm{TM}}$.

a) Evidence 38: Choice of neutron source materials

303. In many cases, the neutron flux in a sub-critical reactor is very low. This makes it more difficult to measure the neutron flux accurately and to be sure that the flux detections are working properly. Having a low neutron flux may also be undesirable for other reasons, e.g. it is conceivable that an incorrect arrangement of fuel and control rods could go undetected if the neutron flux is very low. The solution is to put something in the core that emits neutrons even when the reactor is sub critical, i.e. a neutron source.

304. Spontaneous fission neutron sources make use of the fact that many radioactive isotopes of transuranium elements have an appreciable spontaneous fission decay probability. Neutrons are emitted by some stable isotopes when they are hit by alpha particles emitted by a radioactive isotope, known as the (alpha) reaction. Most (alpha) sources contain a mixture of beryllium and one of several alternative radioactive alpha emitters, e.g. polonium-210 or americium-241. Photoneutron sources rely on the (gamma,n) reaction. The nuclei of some isotopes contain relatively weakly bound neutrons that can be dislodged if the nuclei are hit by photons of gamma radiation of sufficient energy. Photoneutron sources contain either beryllium or deuterium in combination with one of several alternative radioactive gamma emitters, e.g. antimony-124 or lanthanum-140.

305. Photoneutron sources have a number of advantages over either spontaneous fission or (alpha,n) sources for use in nuclear reactors. An important advantage is that a photoneutron source can be made entirely from non-radioactive materials that only begin to emit neutrons after the source has been activated in the reactor core. This makes manufacturing and installing the source cheaper, safer and easier. For example, a photoneutron source can be made from non-radioactive beryllium and antimony. After being installed in the reactor core, the antimony component absorbs neutrons when the reactor is operating at power, resulting in the production of antimony-124, whose gamma emissions dislodge neutrons from the beryllium atoms. A photoneutron source made from non-radioactive materials cannot, for this reason, be used as the neutron source during the very first start-up of a new reactor – a different source must be used instead. This in-situ production of the gamma emitting component of a photoneutron source every time the reactor operates at power also means that the source is constantly replenished. In contrast, the radioactive components of a spontaneous fission or (alpha,n) source decay with time and are burnt-up when the reactor is operating at power.

306. Practical choices of photoneutron sources are very limited. Using a radioactive isotope to provide the gamma photons in the source is convenient, but there are only two isotopes that undergo (gamma,n) reactions with gamma photons of the energies generated in the decay of radioactive isotopes: beryllium-9 and deuterium. Beryllium-9 has the advantage that it can be provided in a convenient physical form that is also chemically and isotopically pure (beryllium metal comprises 100% beryllium-9). The choice of gamma emitter to combine with beryllium-9 is limited to those that generate photons with energy above the neutron binding energy of the beryllium-9 nucleus. There are several possible candidates, but antimony-124 is a popular choice for a number of reasons, e.g. its appreciable half-life (60 days).

307. Antimony-beryllium photoneutron sources have a long track record and were available as long ago as the 1940s and were installed in many early civil nuclear reactors, including Magnox reactors in the UK and PWRs in the USA. Their continued widespread use in reactors to this day is a testament to how well they have performed in this application. Antimony-beryllium sources have continued to be used in most PWRs evolved from the early Westinghouse designs, including the PWRs operated by EDF in France, and are a feature of the two PWR designs having gone through the GDA process in the UK (the UK EPR^{TM} and the AP-1000).

308. Antimony-beryllium neutron sources have also been used in the Sizewell B PWR, another reactor evolved from a Westinghouse design. One feature of the sources that had previously received little attention was brought to light in the early years of Sizewell B operation: the production of tritium in the sources, its escape into the reactor coolant water and its eventual release into the environment. Emissions of tritium in liquid effluents from Sizewell B were higher than expected when the plant started operating and subsequent investigations discovered that the antimony-beryllium neutron sources in the reactor were making an appreciable contribution to the tritium emissions.

309. Tritium is the product of a sequence of reactions, starting with beryllium-9, that occur when antimony-beryllium sources are irradiated in a nuclear reactor:

$$\text{Be-9} + \text{n} \rightarrow \text{He-6} + \text{alpha}$$

$$\text{He-6} \rightarrow \text{Li-6} + \text{beta}$$

$$\text{Li-6} + \text{n} \rightarrow \text{H-3} + \text{alpha}$$

310. Antimony-beryllium photoneutron sources may be the origin of as much as 12 % of the emissions of tritium in liquid effluents from the UK EPR^{TM} units at SZC. Although more than 99 % of the radioactivity discharged in liquid effluents from SZC is expected to be tritium, the resulting dose to the SZC representative person from gaseous and liquid discharges of tritium will be very small (<0.2 µSv y^{-1}).

311. It is proposed to assess the possibility of operating the SZC reactors without antimony beryllium neutron sources. A necessary input to this assessment will be OEF gained when the first EPR^{TM} units are brought into

operation (e.g. Flamanville 3 (FA3), HPC etc.) and when the SZC reactors are themselves operational. It is noted that although it is currently operational, there is currently limited data available from the operational EPR™ at Taishan. Further operational data, where available, will be reviewed as appropriate and will inform decision making with regards to neutron sources. This is covered by [SZC RSR CMT1] of the forward work plan in the permit application head document [Ref 1].

312. The amount of beryllium in the sources proposed for use in the UK EPR™ have been reduced, thereby reducing the production of tritium in the sources; the neutron sources in SZC reactors will contain approximately half the amount of beryllium of those in, for example, the Sizewell B reactor. Any further reduction in beryllium content within the secondary neutron sources may result in a risk of insufficient neutron counts for ex-core detection during refuelling and start-up, which would be an unacceptable safety risk. Therefore, the use of antimony-beryllium sources are considered to be a proven technology and consistent with international best practice. The reduction in the beryllium content reduces the tritium produced.

b) Evidence 39: Choice of neutron source cladding materials

313. As covered in [Ref 5], stainless steel cladding is typically used in antimony-beryllium sources although the cladding is permeable to tritium resulting in the escape of tritium into the primary coolant.

314. There is an option to replace the stainless steel cladding of the sources, which is highly permeable to tritium, with Zircaloy, which is not. The main drawbacks of doing this would be that the sources would be more expensive and would need to be replaced every 5 years, leading to more expense, more radiation dose to operators and more radioactive waste. Use of Zircaloy cladding for the antimony-beryllium neutron sources in the SZC reactors would be considered a risk as the design would be largely unproven. As a result, it has been concluded that this method of tritium reduction does not represent BAT.

6.1.8 Claim 1, Argument 8: Management Arrangements and Operational Controls

315. When a new process or piece of equipment is required, there is a potential for radioactive contamination to occur or additional radioactive waste to be produced.

316. When this occurs, the impact of the activity/equipment should be considered, and a BAT assessment produced. If the generation of waste or contamination cannot be avoided, operational or procedural controls will be used where appropriate to minimise or mitigate the risk of contamination or the production of additional waste.

317. The use of management and operational controls to minimise the amount of radioactive waste or contamination complies with Principle RSMDP3 – Use of BAT to minimise waste, of the RSR – Environmental Principles:

> *"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."*

318. RSMDP3 includes consideration of:

- minimising the production of secondary radioactive wastes over the complete lifecycle of the facility;
- the use option studies, particularly for proposed new facilities or proposed modifications to existing facilities; and,
- considerations during optimising should include the manner of operation, including supervision.

a) Evidence 40: Management Arrangements and Operational Controls

319. The SZC RSR Permit Application Head Document, management arrangements section, [Ref 1] includes details for how management arrangements and operational controls will be governed at SZC.

320. The introduction of an Inspection remote operated vehicle (ROV) to the outfall tunnel could result in the contamination of the ROV and additional radioactive waste produced during decontamination. The use of the ROV was justified as ALARP in MODEM 31 [Ref 58]. Arrangements such as reducing the potential contamination of the ROV by stopping discharges while the ROV is inspected have been identified [Evidence 154].

321. BAT assessments which will take place as part of system level BAT reviews will be required in the future to provide further evidence, such as:

- a BAT assessment on the operation controls of a required hoist has been requested in the future in order to ensure that risk of drops and spills are minimised and reduce the risk of secondary radioactive waste generation; and
- a similar BAT assessment will be required in the future from the designer of dedicated I&C equipment for the TES process.

6.2 Claim 2: SZC Co. Shall Minimise the Amount of Radioactivity Discharged or Disposed of to the Environment

322. The UK EPR^{TM} employs a range of features to reduce the discharge or disposal of radioactivity from those radioactive wastes that are unavoidably created during operations. These features have been selected from a combination of OEF gained from reactors around the world and from the consideration of meaningful alternatives. Taken together they demonstrate that the UK EPR^{TM} has evolved to meet the following requirements of:

- Condition 2.3.2(a) of the proposed standard template of the RSR environmental permit [Ref 20] states that:

  'The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to minimise the activity of gaseous and aqueous radioactive waste disposed by discharge to the environment';

- Condition 2.3.3(a) of the proposed standard template of the RSR environmental permit [Ref 20] that will be granted under the Environmental Permitting Regulations 2010 which states that:

  'The operator shall use the best available techniques to exclude all entrained solids, gases and non-aqueous liquids from radioactive aqueous waste prior to discharge to the environment'.

323. The approach also demonstrates that the following Environmental Principles [Ref 21] have been taken into account during this stage of the programme:

- Principle ENDP15 – Mechanical Containment Systems for Liquids and Gases.
- Principle ENDP16 – Ventilation Systems, where a ventilation system is deemed necessary, it should include appropriate treatment systems to remove and collect airborne radioactive substances prior to discharge of the cleaned gas stream to the environment.
- Principle DEDP4 –Discharges during Decommissioning, means that for every major decommissioning operation that would lead to radioactive discharges the best available techniques should be used to prevent and where that is not practicable minimise these discharges.

324. This claim is consistent with the UK Radioactive Discharge Strategy [Ref 23], it promotes the 'concentrate and contain' principle and discourages dilution and dispersion of radioactive waste into the environment. In general, this means conversion of wastes to a solid form where practicable.

325. It is noted that there is no net benefit from the transfer of these carbon-14 and tritium into a solid waste form. This position is consistent with best practice at PWR's worldwide and was demonstrated as BAT at the GDA stage [Ref 5], with no subsequent developments in technology changing this position.

326. The design of SZC contains a range of features that contribute to substantiating this claim. These features are presented in the arguments and sub arguments that follow this claim. Those that are considered particularly important to this stage of the programme are:

- the provision of containment systems to prevent the uncontrolled spread of radioactivity into discharge systems and thus into the environment;
- provision of abatement systems to remove radioactivity from the waste before it is discharged to the environment; and,
- storage of wastes containing radionuclides with short half-lives prior to discharge which allows some of the radioactivity to naturally 'decay'.

327. Taken together, these features are expected to minimise the activity of the radioactive waste discharged to the environment and to promote the exclusion of entrained matter in aqueous discharges. This will contribute further to reducing the discharges and associated impacts from proposed operations at SZC.

328. Figure 6-2 shows the overarching structure of the Claim, Argument, Sub Argument and Evidence for this Claim. However, as each Argument contains several Sub Arguments, for clarity, individual figures are also included for each Argument to fully illustrate the details of the structure (see Figure 6-3 – Figure 6-9).

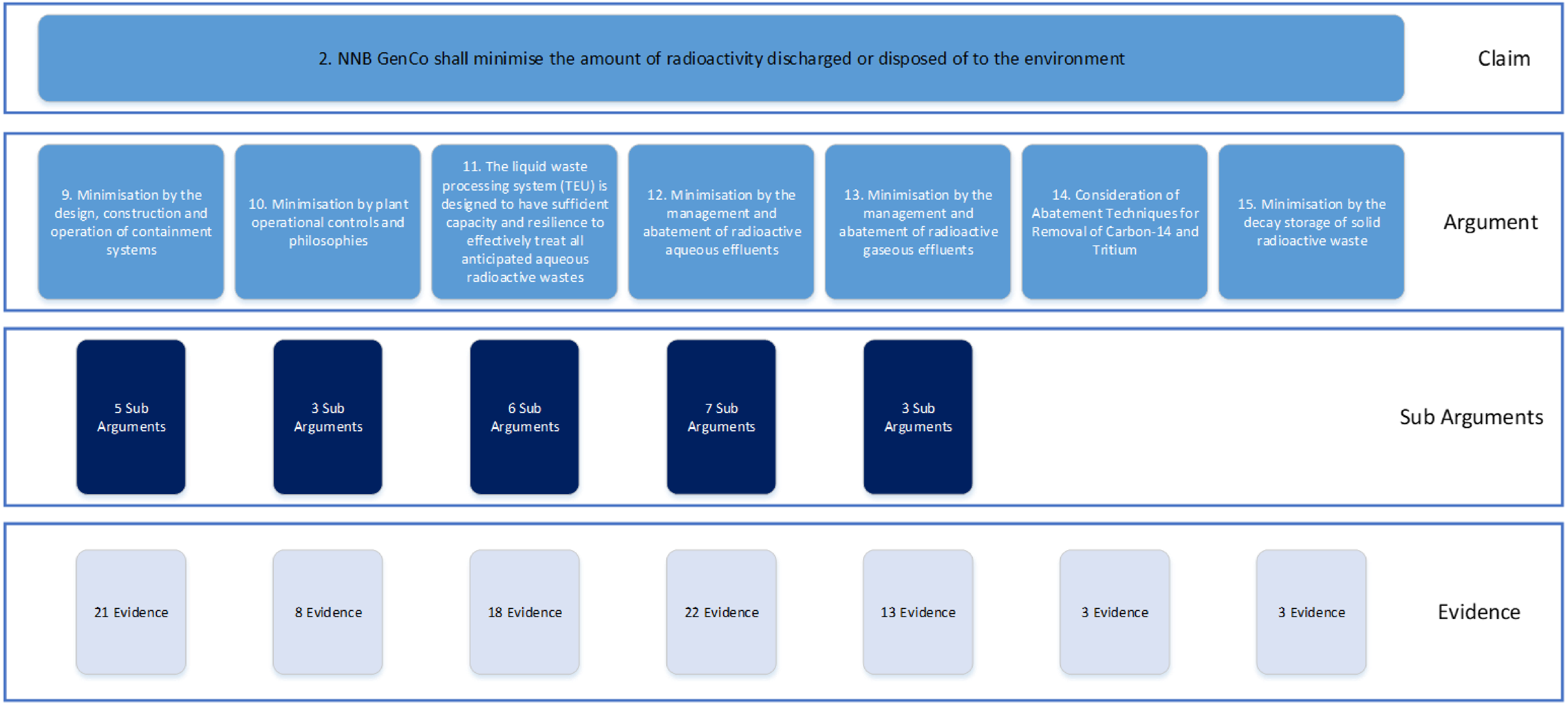


Figure 6-2 Claim 2 Overarching Structure

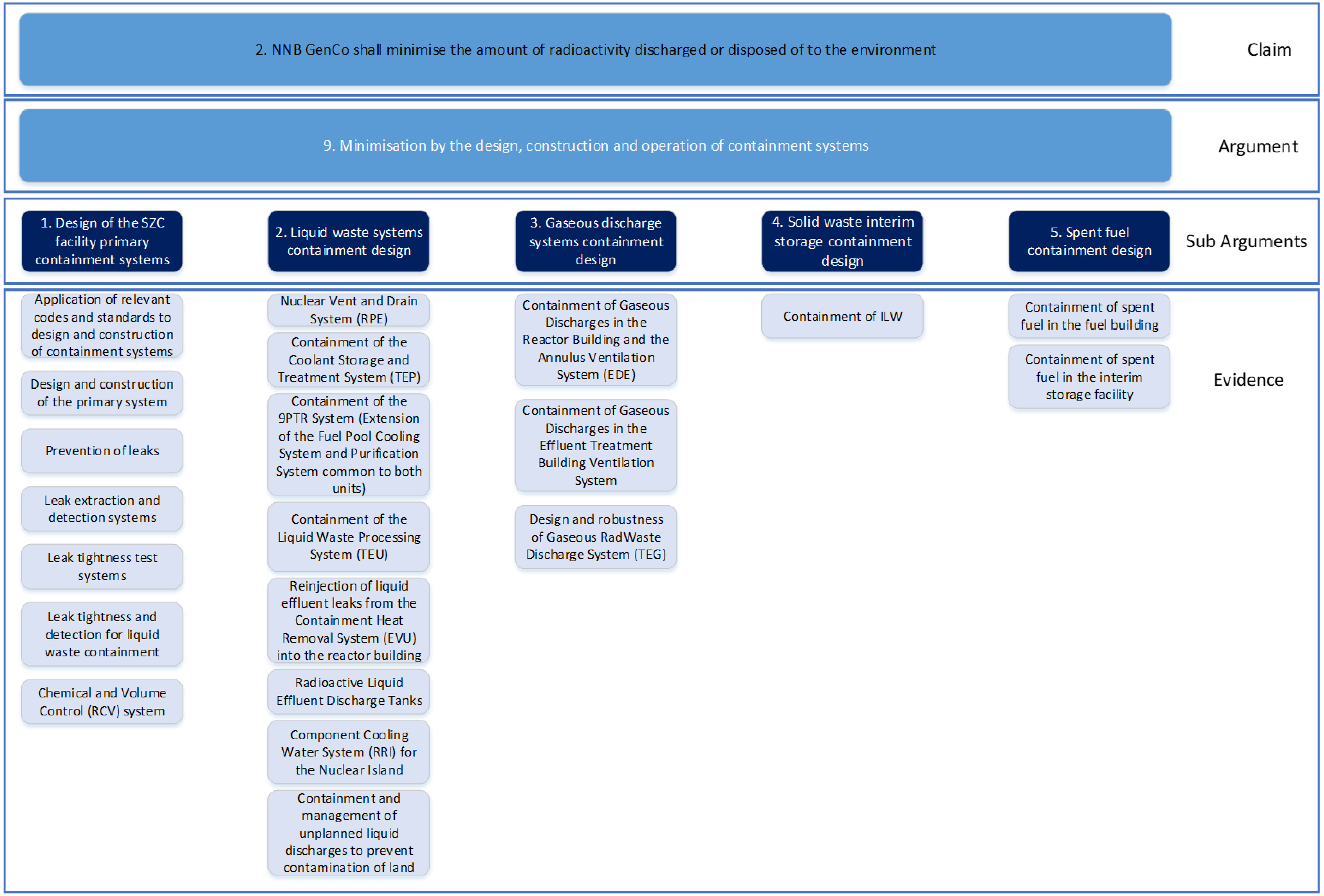


Figure 6-3 Structure of Claim 2 – Argument 9

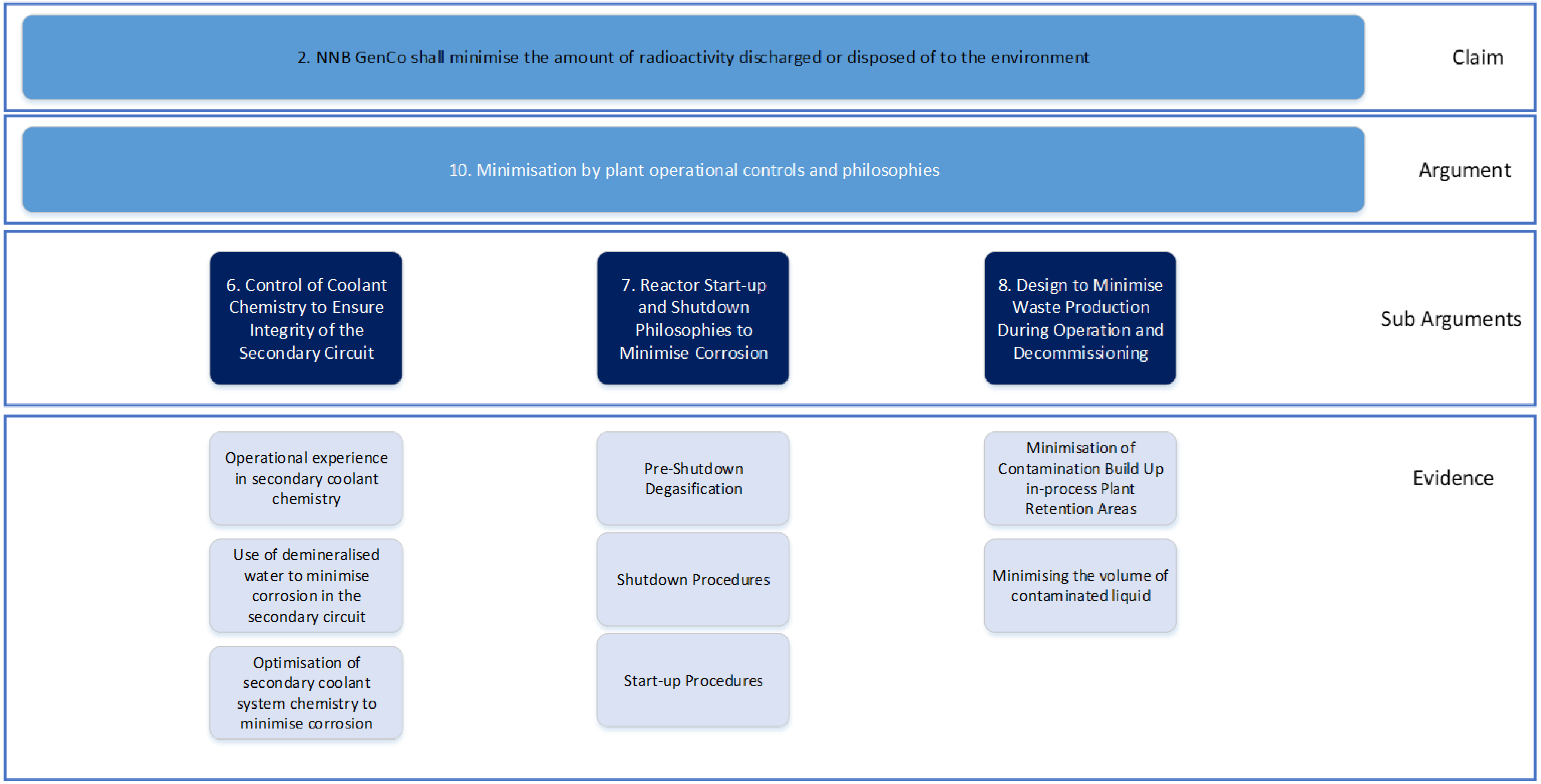
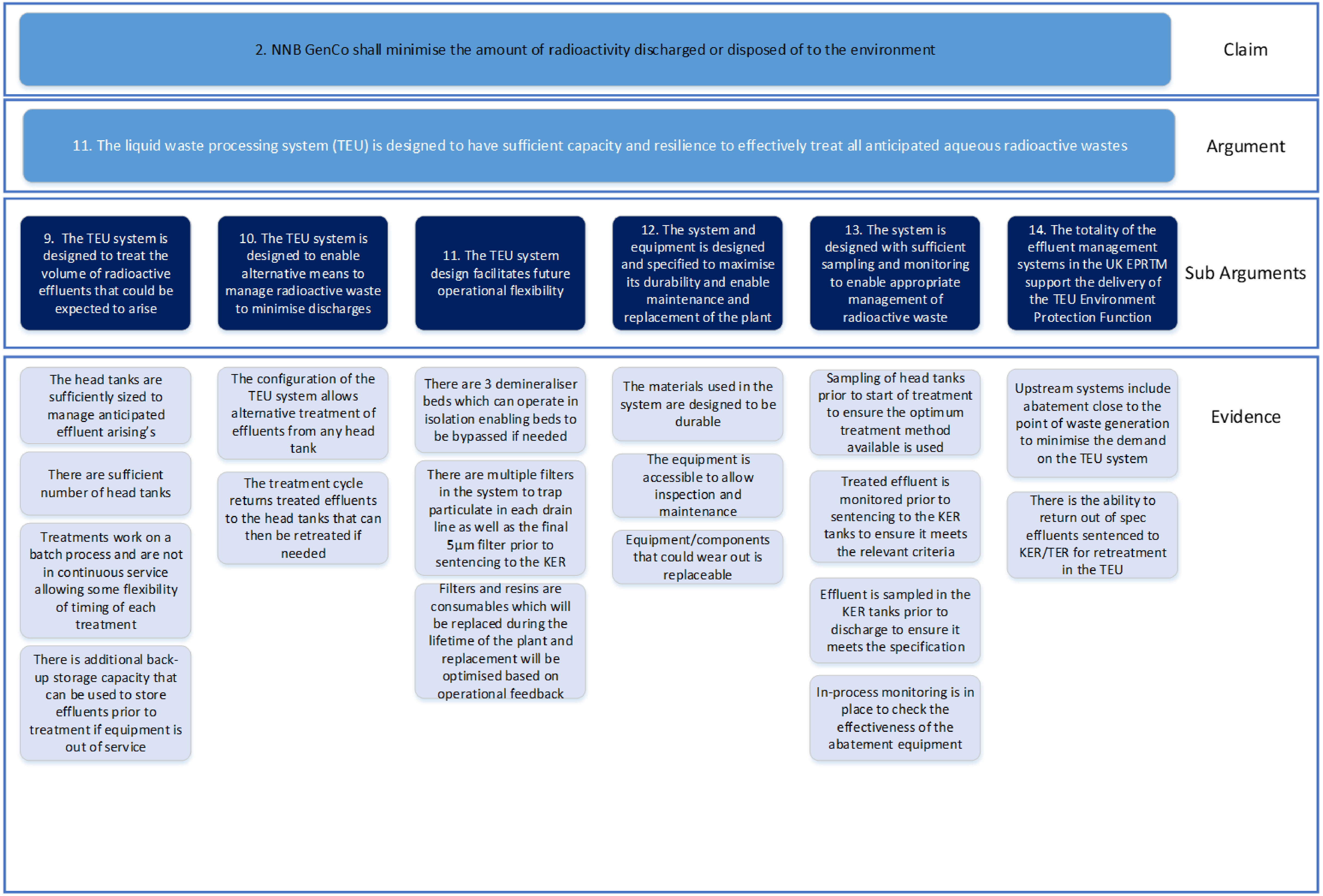


Figure 6-4 Structure of Claim 2 – Argument 10



Claim

2. NNB GenCo shall minimise the amount of radioactivity discharged or disposed of to the environment

Argument

11. The liquid waste processing system (TEU) is designed to have sufficient capacity and resilience to effectively treat all anticipated aqueous radioactive wastes

Sub Arguments

9. The TEU system is designed to treat the volume of radioactive effluents that could be expected to arise

- The head tanks are sufficiently sized to manage anticipated effluent arising's
- There are sufficient number of head tanks
- Treatments work on a batch process and are not in continuous service allowing some flexibility of timing of each treatment
- There is additional back-up storage capacity that can be used to store effluents prior to treatment if equipment is out of service

10. The TEU system is designed to enable alternative means to manage radioactive waste to minimise discharges

- The configuration of the TEU system allows alternative treatment of effluents from any head tank
- The treatment cycle returns treated effluents to the head tanks that can then be retreated if needed

11. The TEU system design facilitates future operational flexibility

- There are 3 demineraliser beds which can operate in isolation enabling beds to be bypassed if needed
- There are multiple filters in the system to trap particulate in each drain line as well as the final 5µm filter prior to sentencing to the KER
- Filters and resins are consumables which will be replaced during the lifetime of the plant and replacement will be optimised based on operational feedback

12. The system and equipment is designed and specified to maximise its durability and enable maintenance and replacement of the plant

- The materials used in the system are designed to be durable
- The equipment is accessible to allow inspection and maintenance
- Equipment/components that could wear out is replaceable

13. The system is designed with sufficient sampling and monitoring to enable appropriate management of radioactive waste

- Sampling of head tanks prior to start of treatment to ensure the optimum treatment method available is used
- Treated effluent is monitored prior to sentencing to the KER tanks to ensure it meets the relevant criteria
- Effluent is sampled in the KER tanks prior to discharge to ensure it meets the specification
- In-process monitoring is in place to check the effectiveness of the abatement equipment

14. The totality of the effluent management systems in the UK EPRTM support the delivery of the TEU Environment Protection Function

- Upstream systems include abatement close to the point of waste generation to minimise the demand on the TEU system
- There is the ability to return out of spec effluents sentenced to KER/TER for retreatment in the TEU

Evidence

Figure 6-5 Structure of Claim 2 – Argument 11

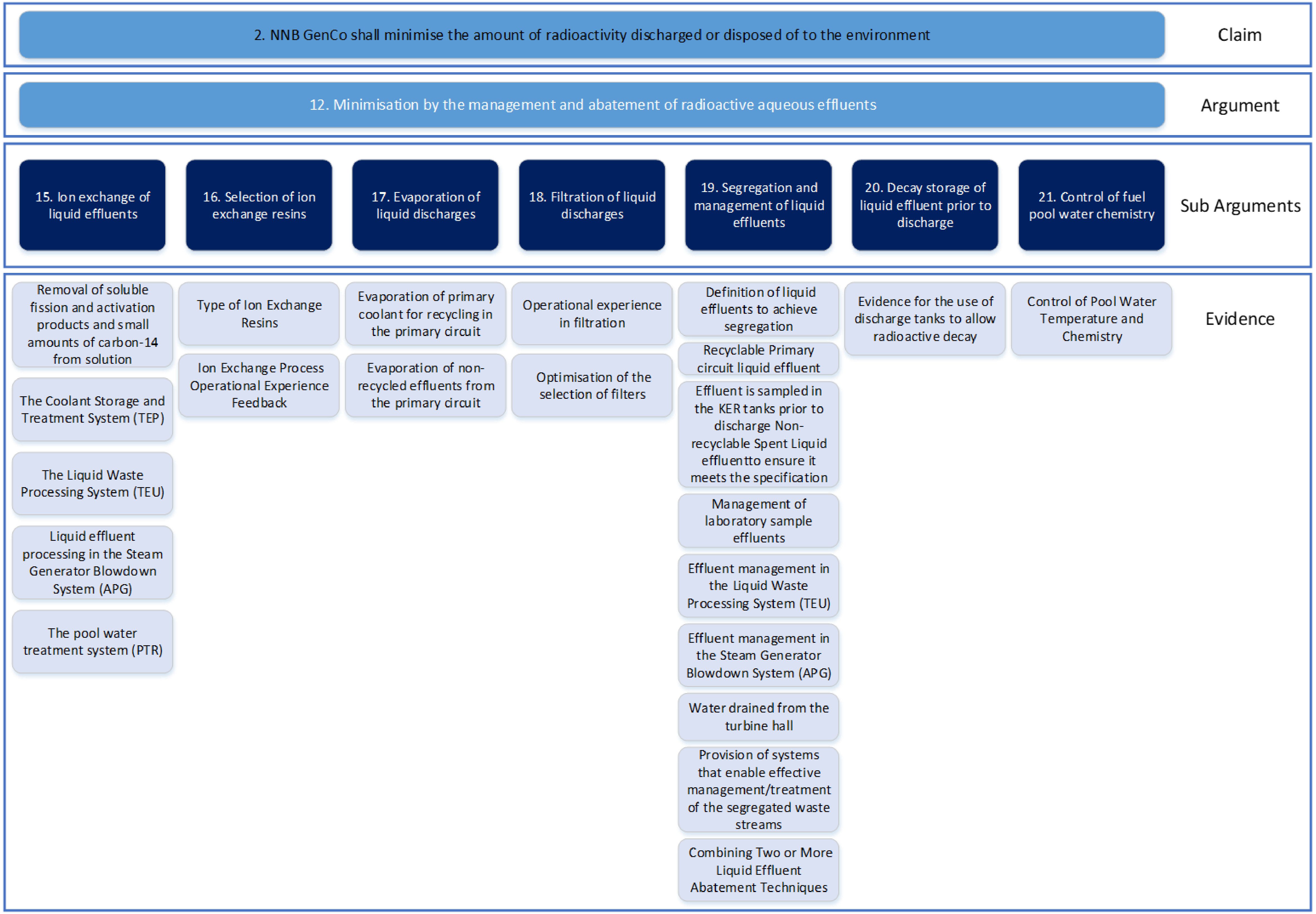


Figure 6-6 Structure of Claim 2 – Argument 12

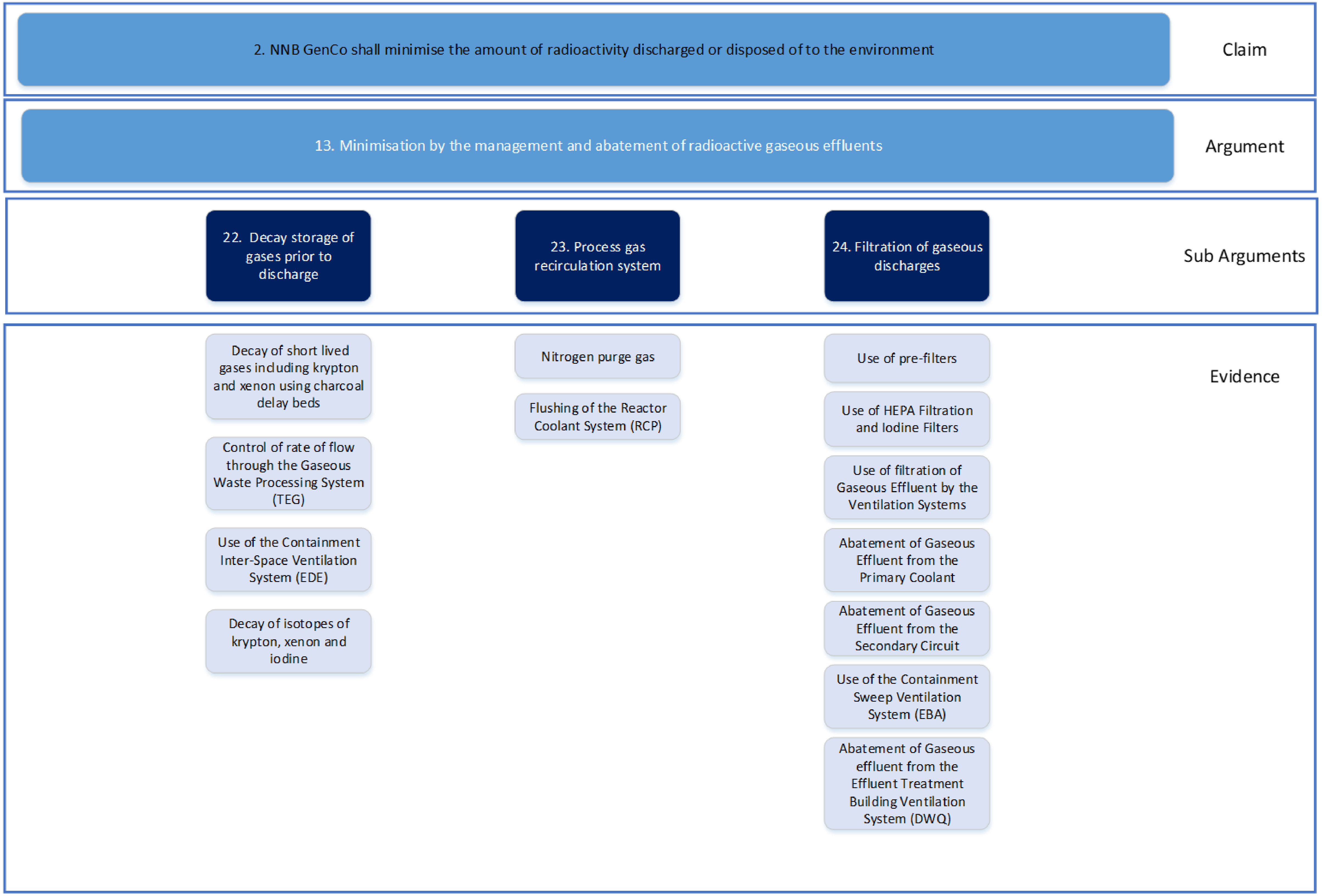


Figure 6-7 Structure of Claim 2 – Argument 13

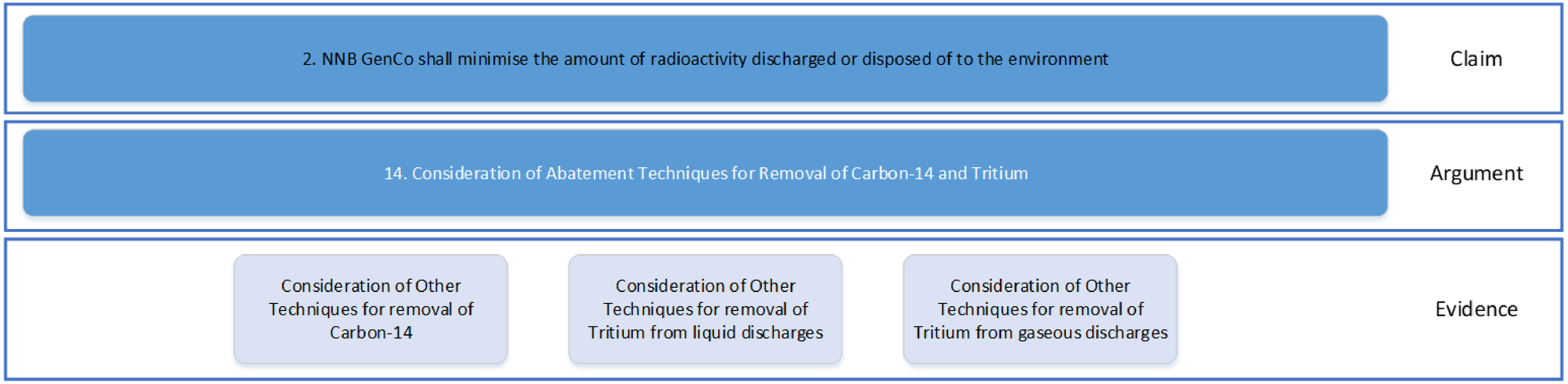


Figure 6-8 Structure of Claim 2 – Argument 14

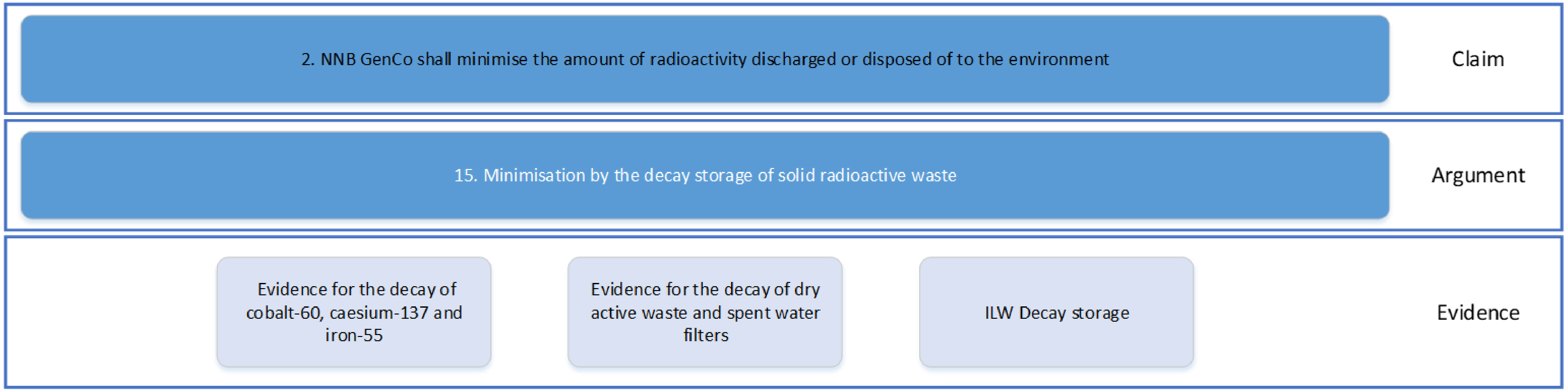


Figure 6-9 Structure of Claim 2 – Argument 15

6.2.1 Claim 2, Argument 9: Minimisation by the Design, Construction and Operation of Containment Systems

329. Containment systems are provided to confine the nuclear matter within the facility and prevent its leakage and escape to the environment in normal operation and fault conditions, except in accordance with authorised discharge conditions, or as part of a planned transfer to another facility. The provision of containment systems to prevent the unnecessary spread of contamination into waste management systems and the subsequent generation of additional radioactive wastes is also a key element of all nuclear installations and facilities and will minimise the radioactivity of the site's authorised discharges.

330. It is important to note that safety and environmental protection have common objectives in the case of containment systems and are met by effective design, construction, operation and monitoring. The safety requirements are articulated in the following SAPs [Ref 22], which are published by the ONR):

- ECV.1 Radioactive material should be contained and the generation of radioactive waste through the spread of contamination by leakage should be prevented.
- ECV.2 Containment and associated systems should be designed to minimise radioactive releases to the environment in normal operation, fault and accident conditions.

331. Demonstration of the minimisation of radioactivity in discharges to the environment is detailed in sub-arguments for the following:

- Design and operational philosophies for the containment systems used at SZC. This includes application of relevant codes and standards for the systems, overview of the primary containment system and details of how prevention and management of leaks is incorporated into the design of plant.
- Design, construction and operation of systems to ensure containment of liquid effluents.
- Design, construction and operation of systems to ensure containment of gaseous effluents.
- Design, construction and operation of systems to ensure containment of solid radioactive waste and spent fuel. This information indicates that the containment of radioactive substances is a key theme in the design of the UK EPRTM units at SZC in terms of ensuring leak tightness and preventing the spread of radioactive materials from the primary and other systems to the environment via the waste management system. This is supported by the removal of pneumatic valves, use of canned rotor pumps and systems and arrangements for the testing of key components for leak tightness to ensure that containment is maintained. It is considered that the containment systems are consistent with the key regulatory principles with respect to environmental protection and that they represent BAT.

6.2.2 Sub-Argument 1: Design of the SZC facility primary containment systems

332. Containment and ventilation systems are provided to confine the nuclear matter within the facility and prevent its leakage and escape to the environment in normal operation and fault conditions, except in accordance with authorised discharge conditions, or as part of a planned transfer to another facility. The provision of containment systems to prevent the unnecessary spread of contamination into waste management systems and the subsequent generation of additional radioactive wastes is also a key element of all nuclear installations and facilities and will minimise the radioactivity of the site's authorised discharges.

333. Effective containment is also of benefit in reducing the quantity of decommissioning wastes by minimising the contamination of materials and components outside the containment systems that will subsequently be disposed of as radioactive waste. The designs of containment measures associated with the systems include:

- reinforced leak tightness requirements for active parts (pumps and valves) and the recovery of primary coolant leaks; and
- provisions to limit the spread of contamination which could result in the generation of waste requiring disposal:
    - through cleanliness/waste zoning defined at the design stage. Areas which could be contaminated in normal and accident situations have been identified;
    - systems are fitted with isolation valves;
    - tanks, sumps and vessels which contain contaminated fluid have suitable containment provided by secondary containment systems, bunding or building structures which can be monitored to demonstrate containment integrity. Floors are equipped with a drainage and collection system
    - leak tight seals prevent contaminated liquids from leaking to ground; and,
    - pipes enclosed in concrete slabs or rafts are double-walled thereby excluding any accidental contamination from escaping into the environment.
- There is no pipework that runs directly through the ground. Where it is necessary to run pipework outside of the nuclear island, or to connect unit 1 and unit 2, containment is provided via concrete galleries.

a) Evidence 41: Application of relevant codes and standards to design and construction of containment systems

334. The main codes and standards used for the containment systems include the:

- Technical code for mechanical equipment (RCC-M [Ref 59]): Initially based on the US ASME code, RCC-M lays down design rules (design basis and analysis of behaviour) and construction rules (specifications for manufacturing and inspection of equipment) for pressure vessels, reactor internals and nuclear island pipework and equipment supports. It codifies French industrial practice and benefits from experience from manufacture, inspection and operation of French units.

335. RCC-M [Ref 59] also lays down design rules for:

- tanks, pressure vessel, mechanical and components part of tank;
- specification of important parts/components in direct contact with the neutron flux;
- leak tightness of equipment; and,
- pumps and valves.

336. It covers the rules applicable to the design and manufacture of pressure boundaries of mechanical equipment of PWRs. The pressure components subject to the RCC-M include the reactor fluid systems (primary, secondary and auxiliary systems) and other components which are not subject to pressure: vessel internals, supports for pressure components subject to the RCC-M and Nuclear Island discharge tanks.

337. EPR^{TM} Technical Code for Civil Works (ETC-C) [Ref 60]: the ETC-C contains rules for the design, construction and testing of the UK EPR^{TM} civil engineering structures. It describes the principles and requirements for safety, serviceability and durability conditions for concrete and steelworks structures on the basis of Eurocode design principles (European norms for structures) together with specific provisions for safety-class buildings and in relation to RCC-M. Evidence 41 covering "design" lays down the essential actions and requirements by which buildings and structures are engineered. The ETC-C applies to the UK EPR^{TM} civil engineering structures such as:

- building, e.g. conception of steel liners, welding, test of containment;
- non-pressure systems and spent fuel pool;
- selection of materials, e.g. steel; and,
- structures such as parts of a building.

338. The ETC-C does not prescribe what type or category of material, e.g. concrete, that is to be used but specifies minimum performance requirements for such materials.

339. As part of HPC RC1.2, a modification was required to the Pressure Differential Smoke Control systems and Smoke and Heat Exhaust Ventilation Systems - (DFL) to meet UK Building Regulations, British Standard BS9999 and BS EN12101-6 wherever possible. These additional requirements support the application of relevant codes and standards to ensure the containment of relevant systems. The application of codes and standards is considered to support the demonstration of BAT as discussed in Section 2.1. As assessed in the design change ranking form the design change will require a further BAT analysis to be undertaken as part of the system level BAT review for relevant affected Heating, Ventilation and Air Conditioning (HVAC) systems (DWN, DWQ, DWL & DWK) [Ref 61]. This is captured as an OP in the open point register [OP 20] [Ref 174].

b) Evidence 42: Design and construction of the primary system

340. The primary system is a closed water-filled pressurised system installed in a leak tight concrete enclosure, the HR. It comprises a reactor, namely a steel vessel containing the nuclear fuel (reactor core) and four cooling loops, each containing a reactor coolant pump and a SG.

341. The HR is cylindrical in shape. The containment is of a "double enclosure" type with a pre-stressed concrete inner enclosure and a reinforced concrete outer enclosure. The containment consists of a cylindrical internal pre-stressed concrete wall and an exterior wall constructed from reinforced concrete, separated by an inter-space called the "inter-containment annulus". The internal surface of the interior containment is covered by a metallic leak tight skin. The internal containment with its leak-tight steel liner together with its internal walls provides the main component of the containment function.

342. The presence of the leak-tight steel liner on the internal containment wall enables the containment leak tightness function to be differentiated from the pressure withstand function. Containment leak tightness is ensured by the liner, whilst the resistance to pressure is provided by the pre-stressed concrete containment structure. The maximum leak rate from the internal containment is 0.3 % vol/day at the design pressure and temperature.

343. The structures and systems contributing to the containment function are as follows:

- The internal and external containment walls (also referenced as internal and external containments), and the space between these walls, called the inter-containment space or annulus. This space is maintained at a negative gauge pressure to collect leaks from the internal containment and to filter them before release into the environment via the stack;

- The systems required for isolating, retaining and monitoring leaks;
- The systems required for maintaining the pressure and temperature conditions inside the containment within the limits that are compatible with the requirements for containment leak tightness and structural integrity; and,
- The shield building protects the containment building from external hazards. The reactor shield building functions as a secondary containment to prevent the uncontrolled release of radioactivity to the environment following a postulated design basis accident.

c) Evidence 43: Prevention of leaks

344. A number of design improvements have been incorporated into the design of the UK EPR^{TM} to prevent leaks. These include:

- The absence of pneumatic valves in the reactor building allows the gaseous waste originating from this building to be reduced. Discharges will be limited to those required in support of the maintenance or commissioning the EBA.
- The pumps of the UK EPR^{TM} REA are designed with canned rotor technology because it suppresses the risk of leaks, which provides a gain in terms of radiation protection.
- The rerouting of a ventilation duct, removing a penetration and so making the wall between the two half buildings of the Fuel Building (HK) watertight.
- The installation of an opening mechanism, between the equipment room and accessible area in the HRA, which will remain closed and leak tight under normal operating pressure (ΔP=200 Pa between the two rooms) in order to meet air tightness criteria in normal operation of 4.5 $m^3/h/m^2$ at 20°C under a ΔP of 2000 Pa, but still allow opening under a pressure of water inside the room resulting from flooding. In such cases the opening of the device should occur as soon as possible in order to guarantee the flow of water toward IRWST and the Safety Injection System (RIS) circulation [Ref 62].

d) Evidence 44: Leak extraction and detection system

345. In order to prevent containment bypass, a leak extraction system is provided at those containment penetrations where there is a potential risk of direct leakage into the atmosphere. Leaks are collected by the Leak Rate Control and Testing System (EPP) and discharged into the containment annulus. The flow in the leak extraction system is driven by the negative pressure created and maintained in the containment annulus by the EDE. Potential leaks from the outer isolation valve are collected and transferred to the containment annulus by the leak extraction system.

346. The EPP monitors containment leak tightness and containment ambient conditions in normal operation. It comprises:

- temperature sensors;
- hygrometers; and,
- pressure sensors.

347. The SEXTEN operation modes for the containment leak test have now been defined and will be included in the EPP System Design Manual (SDM) [Ref 63]. Leak detection for leaks which don’t transit via EDE (space between two HR containments) and leak detection during plant operation have also been defined and will be included

within EPP SDM. These inputs will be taken into account in the Technical Specification of the system in the future.

348. Design changes [Ref 63] have been made in order to perform some leak tightness tests and to test global containment leak tightness criterion. Interfaces between flanges and sleeves have been modified to enable the mounting of the correct sleeve against the penetration.

e) Evidence 45: Leak tightness test systems

349. Three types of tests are used to evaluate the leak tightness of the containment with its steel liner and associated penetrations:

- Type A: overall test which determines the total leak rate from the internal containment;
- Type B: partial test which determines the local leak rate through specific containment penetrations equipped with seals; and,
- Type C: partial test which determines the local leak rates through the containment isolation valves.

350. Before plant commissioning, the internal containment is tested once at the maximum test pressure to demonstrate effective containment design in terms of leak tightness (type A) and pressure resistance. For systems that do not form part of a closed circuit outside the containment, Type C leak tightness tests are carried out if the following three criteria are met:

- The system pipework crosses the internal and external containment walls;
- the system is connected to the containment atmosphere; and,
- the system transports gas.

351. For other systems which form part of a closed circuit outside the containment (such as RIS and the RCV), no Type C leak tightness tests are carried out during outages. However, monitoring of physical parameters, such as pressure and temperature, enables an estimate of the leak tightness to be made.

f) Evidence 46: Leak tightness and detection for liquid waste containment

352. The UK EPR^{TM} incorporates design improvements that aim to reduce the production of liquid chemical and radioactive effluent at source, in particular:

- Reinforced leak tightness requirements for active parts (pumps and valves) and the recovery of primary coolant leaks. This is done by using:
    - bellows seals;
    - reduced number of welds;
    - double barriers made of a double ring joint with a blocked port between the two rings;
    - leak-off lines: a pipe is placed on the valve itself; the connection to the RPE network is then performed by means of a hose pipe; and,
    - double packing pressure seals.

353. Examples include:

- Use of an integrated surge nozzle in the pressuriser lower head will remove a weld from the system which could attract a high radiological dose [Ref 64]. It is probable that the smoother bore profile may also reduce the overall dose in this area.

- Single isolation valves installed between all systems to be drained / vented / flushed to RPE 1 or 4 where pdesign ≤ 12 barg and Tdesign ≤ 100°C;
- Double isolation valves installed between all systems to be drained / vented / flushed to RPE 1 or 4 where pdesign > 12 barg or Tdesign > 100°C; and,
- Draining to RPE 1 and venting and flushing to RPE 4 shall be via fixed connections (where possible) [Ref 65].

354. The leak detection drain pipe on the RCP pump is attached by a flange to the thermal barrier block. The loads on the pump flange transmitted to the pipework exceed the Code levels and can potentially be subject to fatigue loading. Consequently, it has been decided to fit flexible hoses to reduce the loads on the connection. Although, in general flexible hoses are not preferred, in this case their usage is justified [Ref 65].

355. Provisions are being put in place to limit the spread of contamination, including the use of containment measures and systems. The aim is to reduce the risk of contamination of rooms by fluids contained in systems. In particular:

- through cleanliness/waste zoning being defined at the design stage. Areas which could be contaminated in normal and accident situations have been identified;
- systems are fitted with isolation valves;
- tanks, sumps and vessels which contain contaminated fluid have suitable containment provided by secondary containment systems, bunding or building structures which can be monitored to demonstrate containment integrity. Floors are equipped with a drainage and collection system.
- leak tight seals prevent contaminated liquids from leaking to ground;
- wherever possible embedding of pipes and tanks is avoided. This allows inspection and maintenance activities, and facilitates fast leak detection and resolution.
- pipes enclosed in concrete slabs or rafts are double-walled thereby excluding any accidental contamination, which is difficult to remove from the slabs; and,
- the waste building being attached to the Nuclear Auxiliary Building (HN) allows waste treatment before its final conditioning without leaving the controlled area.

356. Further information on specific aspects is provided in the below Evidence.

g) Evidence 47: Chemical and Volume Control System

357. The RCV provides chemical control (e.g. boration) and volume control (e.g. make-up) for the primary system, carrying out the following functions: let-down, containment of leaks from reactor coolant pump seals, make-up, and reactor coolant pump seal injection.

358. Functional requirements include:

- monitoring of leak tightness of the primary system and the primary coolant inventory using means of detection, leak measurement and activity monitoring; and,
- limiting discharges to the environment via recovery of all effluents and by optimisation of effluent discharge against effluent treatment.

359. The components of the RCV are designed, constructed and operated in compliance with the requirements of RCC-M or equivalent standards in order to achieve the required standards for leak tightness and containment. To avoid coolant leakage, all pipe connections and joints must be welded except where flanges are required to facilitate dismantling for maintenance or pressure testing. The welded swing check valves have been replaced by flanged valves [Ref 66]. The principal driver for the modification is that a) flanged valves are easier to procure and fit and b) it gives easier maintenance opportunities on the drains systems. The minor increased risk of flange leakage is justified in the sense that all the valves will be readily accessible to inspect and will have additional benefits from being more easily accessible for maintenance [Ref 67].

6.2.3 Sub-Argument 2: Liquid waste systems containment design

360. Containment and ventilation systems are provided to confine the nuclear matter within the facility and prevent its leakage and escape to the environment in normal operation and fault conditions, except in accordance with authorised discharge conditions, or as part of a planned transfer to another facility. The provision of containment systems to prevent the unnecessary spread of contamination into waste management systems and the subsequent generation of additional radioactive wastes is also a key element of all nuclear installations and facilities and will minimise the radioactivity of the site’s authorised discharges.

361. Systems and storage/discharge tanks for liquid wastes are appropriately sized and designed and constructed to minimise the possibility of leakage. The tanks will offer very substantial hold-up capacity with sufficient capacity to cover all reactor operating scenarios. They will also offer buffer capacity in the event of fault. The design of the tanks facilitates inspection and maintenance activities, and embedded tanks are avoided wherever possible.

a) Evidence 48: Nuclear Vent and Drain System

362. The RPE contributes to the containment of radioactivity. Leakage from circuits and components are collected in the RPE and treated according to their origin. The system helps to limit the retention of activity in the nuclear island buildings and to limit discharge to the environment by monitoring of activity in normal operation. It can also perform containment penetration isolation for the RPE tanks and sumps of the HR (which collect effluents from the annular space and internal structures area) [Ref 68]. Functional requirements include:

- monitoring of leak tightness of the primary system and the primary coolant inventory using means of detection, leak measurement and activity monitoring; and,
- limiting discharges to the environment via recovery of all effluents and by optimisation of effluent discharge against effluent treatment.

363. The components of the RPE are designed, constructed and operations in compliance with the requirements of RCC-M or equivalent standards in order to achieve the required standards for leak tightness and containment.

364. Gaseous effluent is segregated at source and treated in different systems depending on its nature. The gaseous effluent portion of this system collects gases from the RPE tanks of the HR and the HN that receive recyclable bleeds and venting from safety valves, primary leaks and degassing of the pressuriser.

365. Monitoring of leak tightness of the primary system and the primary coolant inventory containment is performed by detection of primary leaks via the primary effluent tank in the HR and using the dedicated cylinder located in the HN. Discharge to the environment is limited by recovering all effluent and by implementing appropriate treatment methods with respect to the characteristics of the effluent collected.

366. Flushing water from the sumps in the RPE was originally recovered from a single settling tank surrounded by a concrete pit, which would collect the contaminated water in the event of the settling tank overflowing. A further two settling tanks have been added to the design, resulting in the provision of two settling tanks and

one overflow tank. This will avoid the risk of contaminated water entering the concrete pit. Leakage is monitored by level sensors measuring the volume collected in the floor drain sumps in the reactor building and the auxiliary buildings.

367. A BAT assessment [Ref 69] details an update to the design of the HN Hot Laboratory drains to the RPE. A new sink will be added to the laboratory for disposal of active samples analysed by the addition of chemicals; the correct disposal route is to RPE5 only previously accessible to operators through using a particular glovebox. The original UK EPR^{TM} design routed all the sinks to the RPE7; mis-consignment of active chemical samples via this disposal route added risk to operators from proximity to the RPE7 sump. The new sink reduces operator burden, minimises potential contamination of gloveboxes (and associated clean-up burden of these facilities). The new sink will be correctly marked to ensure operators only dispose of chemical samples and operational procedures will be modified accordingly.

368. A Baseline Environmental Summary for the 2/9RPE (the drains system for the HVL, HXA, HVD buildings (9RPE) and the HQC building (2RPE) [Ref 215]. The BES summarised the specification for the 2/9RPE sumps.

369. The sumps within 2/9RPE shall be lined with a double-wall stainless steel liner [Ref 26] one of the two stainless steel liners is in direct contact with the structural concrete of the sumps. The second liner is offset from the first, with a 5 cm wide free space between them at the bottom most point. This system allows the detection and recovery of any leakage from the first liner by the second liner, preventing contaminated leakage from spreading into the concrete of the foundation raft.

370. The volume of the sumps have been sized upon a number of factors, mainly related to upstream system requirements, available layout space and operator actions. An analysis on the major sources of effluent and/or major operations that will fill the sump (e.g. flushing operations, tank drainage or pipe drainage) was considered during sizing, the main constraint being to prevent the sumps from being too small, such that any major drainage operations have to continually be stopped because the sump has filled up and needs to discharge.

371. An operator action is not always strictly necessary during the discharge of a sump, as the control system automatically starts and stops the sump pump in the case of a high/low level – however, alarms will be activated and the operator is able to manually start/stop the pumps and take samples if required.

372. The construction of the sumps ensures that the number of welds are minimised, therefore reducing the possibility of leakage. The choice of material has also reduced the probability of leaks by using a non-porous material (i.e. stainless steel lined sumps in preference to concrete sumps with no liner).

373. A binary leak sensor is installed between the two stainless steel sump liners of each sump. The sensor is installed to detect any leaks from the sumps. Evidence 49: Containment of the Coolant Storage and Treatment System

374. The TEP conveys effluents containing radioactivity so its pressure envelope must be designed to contain radioactive products. Where the TEP system contains primary circuit coolant/effluent, evidence relevant to the primary circuit containment (under sub-argument 1) and the RCV system are also applicable to TEP. The components of the TEP are designed, constructed and operated in compliance with the requirements of RCC-M or equivalent standards in order to achieve the required standards for leak tightness and containment.

375. This system also plays a part in retaining radioactive materials in normal operations, thus reducing release into the environment.

b) Evidence 50: Containment of the Liquid Waste Processing System

376. The TEU system is installed in the Effluent Treatment Building. It is provided for storage and treatment of spent, non-recyclable liquid effluent collected by the RPE. This system also contributes to the containment of radioactivity.

377. There are provisions for double containment and directing overflows back to the storage and treatment systems. The front end storage tanks are constructed in stainless steel (to design standard EN14015). They are fitted with high level alarms and installed with sufficient bunding to capture and retain any leaks.

378. BAT assessment [Ref 70] presents the demonstration that the TEU has sufficient capacity and resilience (for example, in case of outage due to maintenance or breakdown) to cope with all the aqueous radioactive waste arising and to ensure that the use of the TEU evaporator is optimised.

c) Evidence 51: Containment of the 9PTR (Extension of the Fuel Pool Cooling System and Purification System common to both units).

379. The 9PTR (an additional means of storing and transferring borated water) is a modification to the existing EPR^{TM} design. It is an extension to the PTR purification system common to both HPC units 1 and 2.

380. The operational purpose of the 9PTR is to ensure water transfer between its tanks and the IRWST/HR Pool of the reactor building of HPC1 and HPC2. This allows to meet the extended Safety Case in plant state E but also to reduce the amount of borated water discharged during unit outages. The two large 9PTR tanks can store all the necessary borated water from the primary circuit that has to be drained from the reactor building during maintenance and inspections happening during outages. Thanks to the two additional 9PTR tanks a large amount of borated water can therefore be recycled and re-used rather than discharged to the environment. This process can be repeated each unit outage.

381. The BES produced for 9PTR [216] sets out the tank design and leak tightness requirements for the 9PTR. The 9PTR tanks design avoids sharp edges and rough surfaces to minimise accumulation of particulate matter and has a flat bottom with a constant inclination (sloping base) on the plinth to send any particulate matter to the drain side of the tanks (ensuring no corners where particulate matter can accumulate). The material used is 316L steel which is inert and corrosion resistant. This helps minimise the creation of particulate matter. The surface finish, in particular the selection of materials, processes that affect the surface finish and final surface treatments, is such that the surface roughness is minimised so far as is reasonably practicable, to minimise the accumulation and retention of particulate matter within the tanks. The design of the tanks is consistent with the requirements from [Ref 73](see evidence 53). In line with design change CSFL5002UK [Ref 77] to the KER/TER/SEK's, the 9PTR tanks are stainless steel tanks instead of steel-lined concrete tanks due to leak-tightness concerns.

d) Evidence 52: Reinjection of liquid effluent leaks from the Containment Heat Removal System into the reactor building

382. It is assumed that after 24 hours of Containment Heat Removal System (EVU) operation following a severe accident that an effluent leak occurs somewhere on the EVU, potentially in one of the safeguard auxiliary buildings (HL) 1 or 4. A flow of 7l/min is assumed [Ref 71].

383. A containment requirement is that EVU leakages do not remain in the HL, but are re-injected into the reactor building. Re-injection is initiated by a new level sensor in the RPE sumps that starts a new pump, delivering leakage water to the IRWST by a dedicated DN50 line with multiple isolation valves. All connections are done locally and manually. The aim is to prevent the spread of contamination and to avoid build-up of contaminated effluents in the auxiliary buildings (HLF & HLI) [Ref 72] and [Ref 17].

e) Evidence 53: Radioactive Liquid Effluent Discharge Tanks

384. Concerning the basic safety function for containment of radioactive substances, the KER, SEK and TER discharge tanks play an active part in ensuring containment and monitoring of liquid radioactive discharges to the environment and, protection of the public from exposure to radiation.

i. Storage Capacity

385. The KER and SEK storage capacity will allow collection, storage and discharge of liquid effluents from the SZC site under normal and exceptional operating conditions. The sizing and operation of these tanks ensure that:

- the tank processing and discharge time is lower than the time taken to fill the other tank(s) in the same system, under any normal operational scenario.
- the total site storage capacity adequately covers estimated annual liquid volume production (including volumes produced during shutdowns and other operational phases that generate the most of effluent); and,
- the size and number of the tanks are sufficient to cover two reactor units.

386. A design study was produced to demonstrate that the SEK storage capacity is sufficient to receive, store and discharge the site conventional effluents and RPE floor drain 3, whilst maintaining operating margins [Ref 73].

387. In addition, the possibility to use the TER tanks provides additional margins to cope with exceptional circumstances. The TER is normally not used. It is kept empty in reserve as a support system for the supply of the KER and SEK. Therefore, the TER needs to allow for a backup capacity for effluents that would normally be routed either to the KER or to the SEK, or for effluent generated in exceptional circumstances. The number and size of the TER tanks should then be equal to that of the KER tanks.

388. The TER is as such capable of storing either:

- the whole volume of effluent that can be stored in the KER; or
- the whole volume of effluent that can be stored in the SEK; or
- effluent that would be generated during an exceptional event leading to an important volume of effluent that could not be wholly stored in the KER/SEK tanks (e.g. multiple unit shutdown or SG Tube Rupture).

389. The concomitance of 2 or more events leading to the use of TER tanks is highly unlikely hence the sizing for the TER tanks is deemed appropriate. This is substantiated by OEF from the EDF PWR fleet in France.

390. Therefore, it is considered that the KER tanks allow sufficient hold-up capacity to cover normal site operating conditions including transients and containment is ensured for all liquid effluent requiring discharge through the KER. Additional buffer capacity is available in the TER tanks in the event of contingencies.

ii. Design to Ensure Minimisation of Particulate/Sedimentation

391. The design of the discharge tanks has been further optimised through assessments [Ref 74] [Ref 75] and [Ref 76]. BAT assessment [Ref 74] presents the design of the tanks to ensure the minimisation of particulate both in the discharges but also the risk of sedimentation or retention on tank walls that may impact representative sampling and lead to a build-up on tank and pipe internals. The findings of this report conclude that the material specification of the tanks will be a minimum of 304L stainless steel and the surface roughness of the tanks shall be justified by the contract design process (production of an EDS). In addition, the report recommends operational requirements (mixing, cleaning). The final requirement is the addition of tap off-filtration capability

on the KER tanks so that in the event that particulate is present in the tank, the operator is able to connect a mobile filtration device. This will be implemented as part of the HPC RC2 configuration.

392. BAT assessment [Ref 76] addresses the HPC RC2 updates for these operational requirements. For cleaning, the use of a removable rotating spray nozzle is to be included in the design. This is in place of a fixed spray ring and offers benefits to flexibility of sourcing appropriate technology and ease of access for maintenance (a fixed spray ring would require the tank to be taken offline to gain access for maintenance/repair). The report also strengthens the requirement for the System Design Manual update to include the already agreed change to the tank bottom design to include sloped bottoms with rounded edges to minimise particulate retention. Finally, the report details the addition of the capability to include mobile filtration units upstream of the recirculation valves on the tank mixing lines; this allows control and minimisation of high particulate in the line should it be required.

393. The radioactive effluent from the KER, TER & SEK will be stored in stainless steel tanks in the HXA building. This means that there are two safety barriers, the steel tank walls and the building wall. An overarching BAT assessment was completed for this design development. Forward actions from the existing BAT assessments on minimisation of particulate from discharges through the detailed design of the tanks, and valve configuration, will need to be incorporated into the next stage of the design and layout. A condition of acceptance for this part of the modification is that the findings from these assessments are addressed [Ref 77].

iii. Design to ensure leak tightness

394. BAT assessment [Ref 75] looks at the valve configuration of the discharge tanks. The report looks at the available options for valves to maximise leak tightness and minimise the risk of effluent passing. This prevents both unauthorised discharges but also prevents the mixing of tank contents. The report presents the valve configuration and specification required for the SZC discharge tanks. BAT assessment [Ref 76] confirms the arrangements and adds provision in the update of the SDM to clarify that only one system can discharge at a time, so preventing erroneous transfers.

f) Evidence 54: Component Cooling Water System for the Nuclear Island

395. The Component Cooling Water System (RRI) contributes to the containment of radioactive substances through the following functions:

- ensuring the integrity of the containment: closure of the RRI containment isolation valves;
- containment of radioactive substances in sensitive areas outside the containment: the RRI must maintain segregation of all equipment containing contaminated or contaminable fluids used in heat exchangers between radioactive fluids and service water discharged outside the plant Essential Service Water System (SEC) in order to protect the environment in the event of a heat exchanger leak; and,
- indirectly contributing to maintaining the primary coolant inventory: cooling of the thermal barriers of the primary pumps which ensure their integrity.

g) Evidence 55: Containment and management of unplanned liquid discharges to prevent contamination of land

396. Unplanned discharges as a result of incidents such as spillages or leaks can arise from:

- liquid radioactive effluent treatment and storage; and,
- turbine hall maintenance and processes.

397. Structures and equipment associated with the process are designed to include drains, so that uncontrolled discharges are collected and returned to the liquid waste treatment system preventing discharges to ground. Polluted water resulting from incident situations (water from fires, or accidentally polluted with chemicals) will be collected and stored in a containment tank. The liquid in the tanks will be analysed and treated on-site as far as possible, or transferred to another tank for shipping offsite for treatment rather than being discharged to the sanitary sewer.

6.2.4 Sub-Argument 3: Gaseous discharge systems containment design

398. Containment and ventilation systems are provided to confine the nuclear matter within the facility and prevent its leakage and escape to the environment in normal operation and fault conditions, except in accordance with authorised discharge conditions, or as part of a planned transfer to another facility. The provision of containment systems to prevent the unnecessary spread of contamination into waste management systems and the subsequent generation of additional radioactive wastes is also a key element of all nuclear installations and facilities and will minimise the radioactivity of the site’s authorised discharges.

399. Containment of gaseous wastes in the reactor building is achieved by installation of a metal skin on the internal wall of the HR which prevents leakage of radioactive gases into the space between the inner and outer containment, the inter-space which is fitted with a ventilation system [Evidence 54].

400. Ventilation systems within the reactor building itself ensure that air in the reactor building is swept, to minimise doses to the operator during shutdowns when the containment building may be occupied. and discharged via the main unit vent stack. Discharges via the EBA are increased prior to and during planned outages, when the high-flow line is in service. Swept gas from the reactor building is discharged via HEPA filters, and if necessary iodine traps.

a) Evidence 56: Containment of Gaseous Discharges in the Reactor Building and the Annulus Ventilation System

401. For the UK EPR^{TM} unit, installing a metal skin on the internal wall of the reactor building limits leakage of radioactive gases into the space between the inner and outer containment. This space is maintained under negative pressure by the EDE collection system with extraction lines fitted with pre-filtration and very high efficiency filtration (HEPA filters)).

402. The reactor shield building and EDE are designed to provide the secondary containment function under the environmental conditions of normal operation, maintenance, testing, and postulated accidents, including protection against the dynamic effects associated with a design basis accident. The EDE maintains the annulus at a sub-atmospheric pressure during normal operations and following postulated design basis accidents, establishing an essentially leak-tight barrier against uncontrolled releases of radioactivity to the environment.

403. The EDE comprises:

- two 100% safety trains, physically separated, equipped with HEPA and iodine filters; and,
- one 100% train used in normal operation, without iodine filters but with HEPA filtration. In the event of a severe accident, this train is isolated by motorised dampers and ventilation is provided by the EDE safety trains.

404. The functions of the EDE are:

- to maintain a negative (sub-atmospheric) pressure in the inter-space between the containment walls in accident situations, in order to collect leakages across the interior wall, including those from the system for collecting leakages of radioactive fluids from inside the pipelines in the case of certain penetrations;

- to discharge air from the inter-space to the stack after passing through HEPA and iodine filters;
- to delay the release of radioactive substances in order to take maximum advantage from the decay of fission products; and,
- to control the flow rate in the HVAC system so that air flows from less contaminated areas to higher contaminated areas. To aid in preventing the spread of contamination, the air sweeping shall be implemented from clean rooms to potentially contaminated rooms. Air renewal rates are 2 volumes per hour for aerosol risk rooms and 4 volumes per hour for iodine risk rooms with 2 dPa less than the neighbouring rooms [Ref 62].

405. The EBA manages the supply, extraction and filtration of ventilation air from the HR. It includes a filtration system with pre-filters, HEPA filters and iodine traps, which are used if high iodine levels are detected. The gaseous effluent is discharged through the HN stack. The EBA system is covered in more detail within Section 6.2.5.3.6.

406. A design change was incorporated into the design to implement a hydrodynamic seal on the reactor coolant pump [Ref 78]. The sealing system comprises three identical hydrodynamic seal stages, each ensuring one third of the total pressure drop and able to withstand full primary pressure. This is to mitigate station blackout situations where an Ultimate Diesel Generator is under maintenance.

407. One of the impacts of implementing HD Seals is that the seal n°3 leak-off line requires a larger diameter compared to that on the HS Seals' configuration. Whereas the HS Seals' leak-off line was monophasic (i.e. liquid), the larger diameter of the HD Seals' leak-off line means the fluid is now biphasic. To manage the hydrogen risk resulting from the degassing of primary fluid in contact with oxygen in the RB atmosphere (possible ingress through the tolerance gap between the pump shaft and leak-off line), a water plug is created to separate the atmosphere of the leak-off tank swept by TEG from the part of the line exposed to oxygen. To prevent gaseous hydrogen accumulating in the leak-off line, sweeping of the line is ensured by HVAC (Containment Cooling Ventilation System (EVR)) however the biphasic leak-off line introduces a surface area across which not only hydrogen, but also radioactive isotopes can degas. Prior to unit outage any activity degassed is recovered by EBA and discharged to the environment via the HN stack.

408. A BAT assessment [Ref 79] was produced to quantify the potential activity in these discharges, and demonstrate that the design change represents BAT, particularly for noble gases as these would not be discharged via abatement equipment in TEG. It was concluded that the minor increase in discharges was negligible in relation to the annual RSR permit proposed for SZC [Ref 2] (<0.01% of the annual limit) and given the significant safety benefits of implementing the design change, it was concluded that it represents BAT.

b) Evidence 57: Containment of Gaseous Discharges in the Effluent Treatment Building Ventilation System

409. The Effluent Treatment Building is equipped with a classified Waste Building Treatment Ventilation containment system (DWQ). In normal operation, extraction is via a HEPA filter. If elevated activity is detected, extraction is automatically switched to the iodine traps. If the ventilation system is unavailable, static containment is applied. HEPA filtration and iodine traps specific to the DWQ system are included within the design, however discharges from the system feed into the main unit vent stack plenum, rather than via a dedicated effluent treatment building stack.

c) Evidence 58: Design and robustness of Gaseous Waste Treatment System

410. A basic functional requirement of the TEG is to contain the radioactive gases in the connected systems and tanks; this is ensured by extraction and treatment of the gases resulting from the degassing of the primary coolant effluents and maintaining the major part of the system under a negative pressure.

411. The closed-loop operation minimises the discharge of radioactive gas to the environment by reusing purging nitrogen once the hydrogen and oxygen content have been reduced to safe levels. The N2 is recycled as much as possible and, when this is not possible, is managed as a gaseous waste. The TEG also processes radioactive gaseous waste to minimise personnel exposure to radiation and to control the release to the environment.

412. A BAT assessment [Ref 80](appended to [Ref 81]) was undertaken following review of the original UK EPR^{TM} design regarding robustness of the TEG for environmental releases as a result of transients and failure modes from over-pressurisation. The review identified where the transients and/or frequency of failure could result in the valves lifting and resulting in an unmitigated release of gaseous waste to the environment. Conservative estimates of short-term additional discharges of the most serious transient occurring assumed that the whole volume of TEG (~240 m^3) would be discharged over the course of 2.4 hours. Which would equal approximately 6 TBq of noble gas activity discharged. A 6TBq release would exceed the Quarterly Notification Level (QNL) of 1.5TBq for noble gases. This release would be discharged via the HN stack bypassing the TEG delay beds where normal abatement of noble gases occurs, though discharge via HN would include HEPA filtration and iodine abatement if required.

413. Changes to the baseline design were recommended in order to reduce the possibility of the identified transients occurring. This included changes to the control logic and automation of valves on the nitrogen injection and delay lines on detection of high pressure protect against failure of the system and to prevent the release of unmitigated discharges.

414. Design change T1EPUK100004 [Ref 81] details the changes made specifically to the RPE1891VJ safety valve, identified as a key control to prevent unmitigated discharges. RPE18 collects primary effluents as a result of overpressure of safety valves from systems in HN and HK (primarily TEG and TEP). The system is protected by a safety valve (RPE1891VP) that originally would have discharged the gaseous/liquid effluents into the TEP maintenance and inspection room; this presented an unacceptable safety risk to operators who may be present in the room. The modification involves:

- In the event of the safety valve being required, appropriate monitoring of the TRP/TEG/RPE systems to ensure an evacuation alarm is sounded in the room to warn operators.
- Redesign of the RPE18 to add a liquid/gas separator to redirect any gaseous discharges to the DWN plenum instead of the maintenance room, the liquid portion will continue to go to the TEP tanks.

415. A gaseous discharge, due to the lifting of this valve via the DWN, could result in a significant reduction in margin with regards to the proposed permit limit for noble gases, with an expected activity of 2.71-8.88TBq discharged compared to the proposed annual limit of 45TBq. This is deemed acceptable due to the extremely low frequency of occurrence of events leading to such a discharge, the fact that current RSR margins are sized to allow for these events (i.e. the need to bypass the TEG delay beds), and that a separate Design Change T1WIT-UK-10456 A [Ref 80] is expected to significantly reduce or eliminate the transients leading to radioactive releases from TEG. Other potential solutions that do not involve sending untreated gaseous effluent to the stack have been analysed, but are not feasible due to worker protection concerns or have been shown to have a significant engineering impact for only a minimal reduction in radioactive discharges (i.e. are disproportionate).

6.2.5 Sub-Argument 4: Solid waste interim storage containment design

416. The general safety functions of the ILW Interim Storage Facility (HHI) for solid radioactive waste include the containment of radioactive substances, through the interposition of sufficient systems of containment between the source of activity and the public and the environment.

417. Containment of radioactive waste in the HHI for ILW is based on isolating the waste from the workers, the public and environment:

- The primary element of containment of ILW is the waste package.
- A second containment system is provided by dedicated, segregated storage facility.

a) Evidence 59: Containment of ILW

418. Containment of solid ILW in HHI is based on isolating the waste from the workers, the public and environment. This is achieved through:

- primary containment in a specifically designed ILW package; and,
- secondary containment provided by the structure and containment functions of the dedicated, segregated HHI.

419. Thus, in the event of loss of package integrity during storage, radioactive substances remain contained inside the building due to the adopted design.

420. The Optioneering Report [Ref 82] presents the conclusion of a fault based assessment of the systems and processes associated with transfer of ILW resin and transfer of spent liquid effluents through the Effuent Gallery (HGQ). The report concludes that to ensure the containment of ILW through the gallery, leakage detection, through the installation of probes on the extremities of the HGQ gallery slab, and collection, through the addition of a gutter on the Radioactive Waste Process Building (HQB)/HGQ interface, has been identified as a candidate design change. In other areas associated with resin transfer, detection and collection provisions are already part of the design, however within the HGQ gallery there is no instrumentation to alert the operator of the leakage. Current design only includes a gutter on the interface of HGQ and HQC. This candidate change would require significant further study of civil design impact, layout and potential extent of mitigation effectiveness to determine feasibility of implementation.

421. An additional study [Ref 83] reviewed the potentially available options for the management of ILW in the form of spent ion exchange resins. The recommendation was for use of an underground pipework gallery between Unit 2 and Unit 1, transferring spent resins by water flushing. Applying an ALARP-based review process, showed that the dominant discriminator was operator doses from maintenance and operation of the plant, closely followed by doses during the decommissioning phase of the plant lifecycle. Positives of the option included that the transfer could be performed with minimal operator intervention when compared to the very operator-intensive task of moving spent resins in individual consignments between buildings. The ability to retain the spent resins within the buildings' containments was also seen positively when compared to the external movement, taking resins outside the buildings, exposing it to external hazards and removing a layer of protection to the environment.

6.2.6 Sub-Argument 5: Spent fuel containment design

422. Containment and ventilation systems are provided to confine the nuclear matter within the facility and prevent its leakage and escape to the environment in normal operation and fault conditions, except in accordance with authorised discharge conditions, or as part of a planned transfer to another facility. The provision of containment systems to prevent the unnecessary spread of contamination into waste management systems

and the subsequent generation of additional radioactive wastes is also a key element of all nuclear installations and facilities and will minimise the radioactivity of the site's authorised discharges.

423. The spent fuel storage pool in the Fuel Building is designed to hold spent fuel for a period of cooling immediately after removal from the reactor and before transfer for long-term interim storage in the HHK where fuel will be stored in dry conditions prior to disposal at the National Geological Disposal Facility (GDF), when available.

424. The spent fuel storage pool involves the storage of spent fuel under water and thus will be designed to prevent loss of water from the storage pools. The system will have associated cooling systems. The storage pool is designed and will be constructed in accordance with the leak tightness requirements of the relevant EPR^{TM} Technical Code ETC-C [Ref 60]. The storage pool will be constructed of concrete with a watertight metal liner and fitted with leak detection systems and containment isolation devices.

425. The design of the dry storage spent fuel store for SZC has been adopted from HPC, a design change for HPC following the GDA changed the strategy for spent fuel storage. The design of the HHK for the longer term on-site storage of the spent fuel after the initial 10-year period in the fuel building pool is undergoing detailed design. The spent fuel storage system and facility has following the change in strategy at the existing PWR in the UK at Sizewell B.

a) Evidence 60: Containment of spent fuel in the fuel building

426. When it is first discharged from the reactors, spent fuel at SZC will be stored underwater in pools. In each case these pools will have sufficient space to store all of the spent fuel for at least ten years.

427. The original design of the cooling pond comprised of two storage regions. The updated storage configuration comprises only one region, which removes the need for a mechanism for determining the irradiation profile and simplifies fuel pool operations [Ref 84].

428. The UK EPR^{TM} pools [in the Fuel Building] are compartments used for fuel storage and handling. Water-tightness of the pools is achieved with a metallic liner covering the pool concrete walls. The pool liner consists of metal panels welded onto anchors sealed into the concrete. It has no structural function.

429. The liner is required to be watertight in order to:

- keep the fuel under water;
- prevent damage to the concrete structure; and,
- ensure radiological protection (containment of radioactive material).

430. The liner must be water-tight, able to be decontaminated, and must resist corrosion and irradiation (demineralised and borated water is slightly radioactive because it is in contact with spent fuel). The requirements for leak resistance of the liner must fulfil the various load assumptions defined in the ETC-C. The watertight liner is made of metal panels of austenitic stainless steel sheets free of molybdenum with characteristics as described in the ETC-C. The minimum thickness is 4 mm for the vertical sheets and 6 mm for the bottom of the pools. The pipes are connected to the pool liner in such a way that no additional stress is placed on the watertight liner. The leak tightness of these connections is checked.

431. A leak detection, location and drainage system is installed in the area of the welds, behind the watertight liner. The leak drainage channels are installed along the anchoring grid of the metal liner, on the vertical walls and on the bottom of the pool. Any leakage is collected from each panel. Each drain can be isolated in order to locate the leak. A flow meter is installed on each drain header inlet. The drains are equipped with isolation valves to control loss of water from the pool in the event of a leak.

432. The metal liner of the pools does not require preventive maintenance. The leak detection system is fitted on all anchors on the liner of compartments in the two pools. All leaks can be detected, located and repaired. Any leak in the pool liner is detected by measuring water flow by means of the leak detection and drainage system. The damaged liner panel can be located to enable repairs. If a serious leak occurs, loss of water from the pool can be stopped using isolation valves located on the drainage channels. Water losses are thus always minimal. This system design is a replica of the HPC design.

b) Evidence 61: Containment of spent fuel in the interim storage facility

433. Only in intact fuel whose fuel cladding is functioning as a containment barrier is placed into a dry storage cask. Containment analysis of the dry storage cask demonstrates that the design of the cask, as well as the materials used in its manufacture and inspection during storage, will ensure that the MPC containment boundary will not be compromised during the full 120-year duration of interim storage. This along with the inert atmosphere within the cask ensures that two containment barriers preventing escape of fission products are maintained. The casks are also placed in a storage overpack to protect it against external hazards. Finally, the dry storage casks have a thermocouple arrangement which measures the temperature difference across the cask which can be used as an indication of a pressure reduction within the cask [Ref 32].

6.2.7 Claim 2, Argument 10: Minimisation by plant operational controls and philosophies

434. Minimising the generation of radioactive contamination and waste generation at source by operational controls at SZC aims to create fewer opportunities for activity and volume of wastes requiring discharge or disposal to the environment.

435. Sub argument 6 details the potential for radioactivity from the primary coolant to transfer into the secondary circuit and eventually to the environment in discharges as a result of cracks or failures in the primary and secondary circuits arising from corrosion processes and degradation of materials. The main aims of secondary coolant treatment are therefore to maintain the integrity of the primary/secondary barrier by limiting the SG tube corrosion risk and limit the corrosion and flow accelerated corrosion risks of the whole of the secondary cooling system, in order to optimise safety, availability and service life of the future unit. At SZC, there are three main elements contributing to the control of the chemistry of the secondary coolant system to minimise corrosion risk and three fundamental design choices for the secondary cooling system will directly influence the chemical treatment of the UK EPR^{TM} secondary cooling system.

436. The secondary coolant water chemistry, when coupled with careful selection of materials for the secondary circuits is considered to be BAT for minimising the risk of activity transferred from the primary to the secondary circuits due to SGs tube leakages. The control of secondary coolant chemistry to minimise corrosion is considered to be optimised and the practices selected based on good practice as set out in EDF company standards and international guidance on secondary water chemistry.

437. Sub argument 7 details the philosophies used for reactor operations to provide flexibility in the operation and management that enable the minimisation of releases into the primary coolant and their subsequent discharge into the environment via the waste management system.

438. Sub argument 8 identifies that the gaseous and aqueous effluent treatment plants included in the UK EPR^{TM} design represent the final barrier in terms of minimising the discharge of gaseous and aqueous radioactive waste to the environment and explains that there are however, many “upstream” techniques which minimise the amount of contamination that even reaches the treatment plants.

6.2.8 Sub Argument 6: Control of Coolant Chemistry to Ensure Integrity of the Secondary Circuit

439. The radioactive waste generated from electricity generation at SZC arises from fission and activation processes in the reactor core, which is transferred into the primary coolant. The primary cooling circuit transfers heat from the reactor core to the secondary circuit to produce the steam which drives the turbines to produce electricity. There is a physical interface between the primary and secondary circuits. There is therefore the potential for radioactivity from the primary coolant to transfer into the secondary circuit and eventually to the environment in discharges as a result of cracks or failures in the primary and secondary circuits arising from corrosion processes and degradation of materials. In addition to these mechanisms tritium diffuses through SG tubes into the secondary circuit and magnetite formed in SG tubes can become neutron activated.

440. The main aims of secondary coolant treatment are to maintain the integrity of the primary/secondary barrier by limiting the SG tube corrosion risk and limit the corrosion and flow accelerated corrosion risks of the whole of the secondary cooling system, in order to optimise safety, availability and service life of the unit.

441. There are three main elements contributing to the control of the chemistry of the secondary coolant system to minimise corrosion risk:

- OEF across the nuclear industry which will be taken into account in the control of secondary coolant chemistry at SZC [Evidence 60].
- Use of demineralised make-up water in the secondary circuit to minimise impurities that contribute to corrosion process [Evidence 61].
- Optimisation of secondary coolant system chemistry, including maintaining pH, through the use of organic amines, and maintaining reductive conditions and oxygen scavenging with hydrazine injection. Collectively these help to minimise the transport of corrosion products [Evidence 62].

442. Three fundamental design choices for the secondary cooling system will directly influence the chemical treatment of the UK EPR^{TM} secondary cooling system:

- the absence of copper materials;
- the use of stainless steel for elements that are highly sensitive to the flow accelerated corrosion phenomenon (diphasic water/steam medium); and,
- no continuous condensate polishing treatment.

443. EDF will specify secondary coolant chemistry for the operation of SZC in order to minimise corrosion in the secondary circuit. This will be based on review of OEF across the French fleet of PWRs and will take account of international experience including reference documents such as the PWR Secondary Water Chemistry Guidelines produced by EPRI [Ref 85]. This specification will include conditions relating to the use of demineralised water, the pH to be achieved, and the substances to be used for pH control. The amines to be used are widely used in PWRs and there is extensive OEF which supports their use at SZC. The use of volatile amines for secondary chemistry control to achieve a constant alkaline pH in the system is best practice for minimising corrosion in PWR secondary circuits.

444. The secondary coolant water chemistry, when coupled with careful selection of materials for the secondary circuits, is considered to be BAT for minimising the risk of activity transferred from the primary to the secondary circuits due to SGs tube leakages. The control of secondary coolant chemistry to minimise corrosion is considered to be optimised and the practices selected based on good practice as set out in EDF company standards and international guidance on secondary water chemistry. Information that allows the optimisation of secondary coolant system chemistry will be provided by the RES – Secondary Side.

a) Evidence 62: Operational experience in secondary coolant chemistry

445. Water chemistry is recognised in the nuclear power industry worldwide as playing an important role in the degradation of materials including SGs and reactor components. The need for optimisation of water chemistry for nuclear power plants is internationally recognised [Ref 86]. EPRI has issued chemistry control guidelines [Ref 85] for both primary and secondary water chemistry, where control is focused on minimising activity generation and transport and on reducing corrosion damage and the need for maintenance and also publishes information by means of conferences and other publications. These guidelines are kept under review in discussion with reactor operators.

446. OEF gained on EDF's fleet of operating PWRs has identified a number of considerations that need to be addressed in the optimisation of control of secondary coolant system chemistry.

447. Steam and liquid phases of water are present in the various circuits of a PWR. The high heat flux and flow rates induce important concentration processes and the transport of chemical components in various proportions in the liquid and vapour phases, depending on chemical properties and temperature [Ref 41].

448. A number of aspects of the operation of the secondary coolant system present challenges to the control of chemistry of the secondary coolant system. These include the wide temperature range associated with the system (ranging from 40°C in the condenser to 285°C in the SG), the high evaporation rates which can cause high concentrations of chemicals which are not volatile in various parts of the circuit, and the presence of both steam and liquid phases in the system which requires the use of volatile reagents in order to maintain pH control throughout the circuit.

449. In addition, there may be several types of materials which are exposed to secondary coolant in the system and which may have differing properties in terms of their propensities to corrode in the presence of coolant. Some chemical impurities may concentrate in particular areas of the system where they may present an increased risk of corrosion damage to the circuit, particularly to SG tubing.

450. In addition to the corrosion of materials, other issues must be considered when selecting the water treatment control agent and the pH to be used. These include:

- corrosion transport to the SG, giving rise to deposits where corrosion might occur;
- impact on blowdown demineralisers;
- low toxicity of reagents and acceptable releases to the environment;
- commercial availability and cost;
- thermal stability and type of decomposition products; and,
- required concentration for the desired pH [Ref 41].

451. National and international operating experience of condensate ingress events and condensate contamination strategy has been reviewed [Ref 86] and the design of the UK EPR^{TM} has been found to be coherent with identified best practices. An ALARP analysis performed on the existing design and three alternative solutions to condensate contamination strategy found that the existing design was considered to be the most appropriate option to mitigate the risk of a significant ingress of impurities. This report concludes that, subject to work planned by AREVA (now Framatome) that aims to justify SG tubing performance, the risk of condensate contamination from a condenser tube rupture on the existing design of the UK EPR^{TM} is ALARP.

b) Evidence 63: Use of demineralised water to minimise corrosion in the secondary circuit

452. The best available demineralised make-up water is used to fill the secondary circuit in the UK EPR^{TM} units at SZC. The use of demineralised water minimises the presence of impurities in the water, such as chloride and sulphate compounds, that could contribute to the concentration and ultimately corrosion processes.

453. This ensures integrity of all primary (and secondary) circuit structural components (e.g. avoidance of stress corrosion cracking) and avoids build-up of silica deposits on fuel rods (that can allow formation of zeolites). It also minimises requirements for let-down of coolant from the primary circuit and other systems due to impurity levels rising above those given in the relevant reactor coolant specifications (such as silica, sulphate, chloride).

c) Evidence 64: Optimisation of secondary coolant system chemistry to minimise corrosion

454. At any time during the operational phase the water of the various circuits may require the addition of chemicals, in order to maintain the fluid characteristics within the design limits to avoid corrosion.

i. Optimisation of pH

455. In the absence of pollution, the choice of the pH value in the case of all volatile treatment has little impact on the corrosion of the SG tubes, given their grade (690 alloy). However, the pH value will be determined to minimise the risks of corrosion and especially flow accelerated corrosion of non-alloy or low-alloy materials that make up the secondary cooling system components in the turbine room and reduce oxide transport to the SGs. The considered pH temperature value (an envelope temperature of 175°C is admitted with regard to the flow accelerated corrosion phenomenon) is 6.65±0.1.

456. Another important aspect to be taken into consideration is the statutory environmental aspect that imposes limits on amine and nitrogen concentrations in liquid discharges. Therefore, the choice of the optimum pH must make allowance for these various input data.

457. Various amines have been examined in relation to the flow accelerated corrosion phenomenon to reach the optimum pH for the secondary coolant, incorporating the following criteria:

- The stability, nature and effects of thermal decomposition products.
- APG ion exchange resin management.
- The standards for liquid wastes discharged into the environment.
- The consequences of this treatment on SG fouling.

458. In addition to the operational requirements account needs to be taken of the requirements for pH control during shutdown to minimise corrosion during their lay-up. The feedwater plant for the secondary circuit is kept dry during shutdown. The SGs are potentially treated during shutdown with hydrazine, morpholine or ammonia or ethanolamine.

459. The decision made in the design not to install continuous condensate polishing in the UK EPR^{TM} has an impact on the selection of the chemicals used for secondary coolant chemistry control. Lowering the concentration of the basic compound needed for pH control reduces the load on secondary circuit blowdown demineraliser resins, extends resin lifetimes and thus is of benefit in reducing waste arisings, as these resins are not regenerated.

ii. Selection of pH reagents

460. Volatile reagents for minimisation of corrosion are necessary to ensure that pH control is achieved throughout the circuit. Volatile amines are used widely in the nuclear industry to reduce the transport of iron which

contributes to sludge build-up in the secondary circuit. Amines, such as ethanolamine, are known to provide good pH control and to minimise corrosion in materials, such as carbon steel [Ref 86].

461. The main objective of the pH reagent selection is to obtain the conditions for the lowest possible corrosion rate of the different materials present in the whole steam water system. For the UK EPR^{TM} the chemical specification will be adapted to the amine selected for chemical conditioning. The choice of steels has been made based on the experience of operating older PWRs in which carbon steel has been used in high pressure heaters and copper alloys used in old condensers and some low pressure heaters or moisture separator reheater tubing, both of which are compatible with a limited range of pH [Ref 41].

462. In order to obtain a pH which results in lower levels of corrosion, chemical treatment consists of a base compound injected into the secondary circuit, such as ammonia, morpholine and ethanolamine. Lay-up is supplemented with hydrazine to eliminate oxygen in the feedwater and to prevent fouling of the SGs caused by corrosion products (mainly iron oxides). EDF reviewed OEF both from its own reactors in France but also wider international experience, in selecting the substances to be used for pH control in the secondary coolant system. The basic options appraisal focused on the following amines:

- Ammonium hydroxide.
- Morpholine.
- Ethanolamine.

463. Each of these compounds have advantages and disadvantages, for example in terms of protecting carbon steel against erosion and corrosion, fouling the SGs and producing oxide slurry, or managing the discharge and waste products. These substances, together with hydrazine, are described briefly below.

iii. Ammonia:

- Is simpler to use, as some is produced from the thermal decomposition of hydrazine. It will also readily maintain the minimum-corrosion pH in the feedwater plant in a monophasic medium.
- Conditioning is supplemented with hydrazine to eliminate oxygen in the feedwater and to prevent fouling of the SGs caused by corrosion products (mainly iron oxides).

iv. Morpholine:

- Is a weak volatile base. At 25°C, its pH is alkaline, and it is not concentrated by evaporation in the SGs, as are non-volatile reagents. It is therefore used to condition the secondary circuit to achieve the pH that best inhibits corrosion.
- Has a dissociation constant that reduces less with increasing temperature than does that of ammonia. It spreads uniformly throughout the circuit, so that the pH at increased temperatures is higher, and hence all the circuit equipment is protected against corrosion and erosion.
- Conditioning produces less suspended material than does conditioning with ammonia. In theory, using morpholine extends the life of the resins in the SG blowdown system, which reduces waste.
- Is too weak a base to reach the feedwater pH of 9.7 at 25°C required by the chemical specification, so additional ammonia is necessary. It is supplied partly by the decomposition of hydrazine injected into the feedwater station to remove traces of oxygen. If the hydrazine produces insufficient ammonia, extra ammonia is added (mixed conditioning).

v. Ethanolamine (C_2H_7ON):

- Is a weak volatile base that provides the required pH for minimum corrosion across the entire steam-water system. Similar to "non-volatile" reagents, it is not concentrated by evaporation in the SGs.
- The quantity injected can be 2 to 3 times less than that of morpholine, and as it has a good partition coefficient for the liquid phase, it protects equipment well in a biphasic medium.
- Is widely used in the USA and other countries with PWR units. The main advantage of ethanolamine is the lower molar concentration needed, as compared to morpholine, to achieve the target pH at operating temperature [Ref 41].
- Conditioning is supplemented with ammonia from hydrazine decomposition. If the hydrazine produces insufficient ammonia, extra ammonia is added (mixed conditioning).

vi. Hydrazine:

- Is a weak volatile base used in the circuits mainly as a reducing agent. When the secondary circuit is operational, hydrazine maintains a non-oxidising environment, reduces the oxygen dissolved in the feedwater and limits oxide production in the feedwater plant.
- Is decomposed in two ways:
  - by reaction with the oxygen in the water to form water and nitrogen;
  - by thermal decomposition to form nitrogen, hydrogen and ammonia; and,
  - is used to condition the SGs during shutdown.

464. The main objective of the hydrazine regime for the SGs is to minimise the risk of corrosion of high alloy materials, in particular the SG tubing [Ref 41]. Whichever conditioning compound is used to maintain the pH for minimum corrosion, ammonia will always be present in the secondary circuit for two reasons:

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

465. A Design Authority Decision Note [Ref 87] for the choice of conditioning agents was produced which demonstrated that a mixture of ethanolamine (ETA) and ammonia (NH_3) is the most appropriate conditioning amine for the secondary circuit. This decision was made after evaluating the available amines in terms of their distribution throughout the systems, the quantities to be injected to obtain the target pH, environmental impacts, their thermal stability and the impact of any decomposition products, their influence on the operation of blowdown resins and their impact on materials.

6.2.9 Sub-Argument 7: Reactor Start-up and Shutdown Philosophies to Minimise Corrosion

466. Start-up and shutdown of the reactor increases the potential for the generation of corrosion products, such as iron, chromium, nickel and cobalt within the primary coolant circuit. The risk of corrosion occurring is mostly minimised by the primary coolant chemistry in operation the specification of materials and components. However, where corrosion products do exist within the primary coolant circuit, there is the potential for them to enter the primary coolant during start-up and shut down. Philosophies have been adopted within the UK

EPR^{TM} design that provide flexibility in the operation and management that enable the minimisation of releases into the primary coolant and their subsequent discharge into the environment via the waste management system.

467. Rapid heating and cooling of the fuel can cause the fuel cladding to crack. The amount of fission products released into the primary coolant is dependent on the fuel rod power, the fuel rod burn-up, the size of the defect and the number of defective fuel rods in the core. Fission products, such as noble gases and isotopes of iodine, are therefore removed from the primary coolant circuit during start-up and shutdown in order to minimise the amount of radioactivity discharged to the environment in the event of fuel failure.

468. The philosophies that are able to be implemented by the UK EPR^{TM} design during shutdown and start-up include:

- Pre-Shutdown Degasification. The primary coolant degasification system can be used prior to shut down in order to reduce the level of fission gases in the primary coolant in the event of fuel failure. During shutdown, forced oxygenation is undertaken by hydrogen peroxide injection to reduce dose to workers during maintenance and control the ‘crud’ burst that inevitably occurs at shutdown [Evidence 63]. Following plant shutdown and prior to opening the reactor pressure head, the reactor pressure head can be flushed with Nitrogen in order to remove noble gases and volatile iodines and other potential fission products from the primary coolant, minimising their release into the waste management system [Evidence 63];

- Shutdown Procedures. A cold shutdown procedure can be carried out following hot shutdown, resulting in the oxygenation of the primary circuit. This procedure allows for the controlled release of corrosion products into the primary coolant from in-circuit and fuel cladding surfaces, known as a ‘crud burst’ and corrosion product ‘spiking’. Corrosion products are subsequently removed from the primary coolant under controlled conditions through liquid abatement techniques. The high flow rate purification is used in order to accommodate the additional corrosion products which are released, including cobalt-58, cobalt-60, manganese-54, iron-59 and chromium-51. The high flow rate purification also aims at retaining high dose pollutants such as silver-110m, antimony-122 and antimony 124. The generation of corrosion products under controlled conditions will therefore minimise the release of corrosion and fission products into the waste management system [Evidence 64].

- Start-up Procedures. The primary coolant circuit can be pre-conditioned during start-up following re-fuelling in order to remove any residual corrosion products. The purification unit will be operated, ensuring that the concentration of nickel within the primary coolant is reduced. This will subsequently minimise the amount of radioactivity discharged into the waste management system.

469. The start-up and shutdown procedures which can be implemented within the UK EPR^{TM} design for SZC therefore enable a significant contribution in minimising the release of corrosion products from the primary coolant into the liquid effluent system through containment and abatement. In addition, the removal of fission products during start-up and shutdown in the event of fuel failure ensures the minimisation of radioactivity discharged to the environment via the TEG. Further optimisation will be employed during commissioning and operations in order to ensure that radioactive discharges to the environment are minimised.

a) Evidence 65: Pre-Shutdown Degasification

470. The primary coolant degasification system is mainly used to reduce the level of fission gases in the primary coolant during normal operating conditions and particularly before shutdown. The flow rate through the on-line degasification system is set to 72 te h^{-1}, set on the RCV let-down line.

b) Evidence 66: Shutdown Procedures

471. On the basis of the OEF from various countries and theoretical studies on corrosion products behaviour the recommended cold shutdown procedure following hot shutdown provides for:

- the reduction in hydrogen content related to the activity of any corrosion products;
- the removal of lithium from the primary coolant to decrease pH except in the case of high iodine activity;
- elimination of fission products from primary coolant (in case of fuel fail);
- forced oxygenation of the primary coolant by injecting H_2O_2 (sustained with air injection); and,
- starting the highest purification flow rate as early as possible. The RCV let-down flow on UK EPR^{TM} has been considerably increased for this purpose, in relation to the existing French power plant units, flow at 72te h^{-1}, thus doubling purification capacity.

472. For a short period prior to shutdown (72 hours) and during start-up, the purification rate may increase up to 72te h^{-1} to double the purification capacity of additional corrosion products (cobalt-58, cobalt-60, manganese-54, iron-59, chromium-51, etc.) which are released during the forced oxygenation phase (also referred to as 'crud burst') of the primary coolant, which occurs prior to reactor cold shutdown. This purification rate increase also aims at retaining high dose pollutants such as silver-110m, antimony-122 and antimony-124.

473. Primary coolant samples obtained via the REN are analysed to determine the radioactive composition of the primary coolant and identify any cladding failures. Upon discovery of an increase in predefined fission product inventory levels, the plant is to be shutdown to identify the source of the increase and minimise potential dose rate increases.

c) Evidence 67: Start-up Procedures

474. As regards post-refuelling start-up, chemical treatment avoids corrosion risks and also limits the corrosion products source term, primarily by efficiently removing the released nickel from primary coolant.

475. The following main operating phases are envisaged to do this:

- static and dynamic venting;
- starting the online degasser as early as possible at the maximum flow rate on the RCV, to reduce the dissolved oxygen concentration;
- setting the purification unit on the RCV to remove the residual corrosion products at low temperature. The nickel concentration reduction target should aim for below 100–150µg kg^{-1}, provided the primary coolant temperature has not reached 120°C;
- hydrazine injection from 80°C to remove the residual oxygen, to achieve a criterion of $O_2 < 100$µg kg^{-1};
- total Boron Concentration, value required by fuel management to manage criticality; and,
- the hydrogen and lithium hydroxide will be injected into the primary coolant when the reactor has reached the hot shutdown state.

476. By optimising the chemistry control during reactor start-up phases (nickel monitoring) the release of fission products during transients is also controlled

6.2.10 Sub-Argument 8: Design to Minimise Waste Production during Operation and Decommissioning

477. The gaseous and aqueous effluent treatment plants included in the UK EPR^{TM} design represent the final barrier in terms of minimising the discharge of gaseous and aqueous radioactive waste to the environment. There are however, many "upstream" techniques which minimise the amount of contamination that even reaches the treatment plants.

478. In this sub argument a description of some of the important, if less obvious, design features of the UK EPR^{TM} which prevent/minimise the amount of radioactive waste that will enter the effluent treatment plants and hence reduce the level of discharge to the environment. Such features represent an important aspect of BAT for SZC and support the claim that the BAT has been used to minimise the amount of radioactivity discharged to the environment. The main relevant design features can be grouped as follows:

- Minimisation of contamination build-up in "retention areas" of process plant. The process plant within the reactor core, the NSSS and ancillary systems has been designed to minimise retention areas/voids and maximise drainage. In a poorly designed facility, materials can accumulate in retention areas, potentially causing corrosion and increasing the spread of contamination throughout the reactor, this in turn increasing worker doses and the amount of activity that is discharged to the environment in the gaseous and aqueous exhaust streams. Some examples of the type of UK EPR^{TM} design features to assist in this area are described further in Argument 2. Corrosion is also minimised by the selection/specification of corrosion resistant materials within the design; further information relating to the specification of materials and components is provided in Argument 4.

- Rooms, systems and materials used. Specific measures have been taken in order to minimise the creation, transportation and deposition of contamination and to minimise the contamination/activation of rooms, systems and materials. Materials have been chosen based on their likelihood to become radioactive, either by activation or by the deposition/absorption of contamination. Wherever possible equipment will be designed such that surface (radioactive) contamination can be safely removed using methods that minimise the generation of radioactively contaminated gaseous or aqueous discharges. Similarly, wherever possible, equipment will be designed to facilitate its safe disassembly, again in a manner that minimises discharges to the environment. Some examples of relevant design features are provided in Sub Argument 8. In terms of the selection of materials in order to reduce the likelihood of activation, information on relevant design features to support this claim is provided in Argument 4.

a) Evidence 68: Minimisation of Contamination Build Up in-process Plant Retention Areas

479. Retention areas in process plant (e.g. within coolant and ancillary treatment circuits) allow the accumulation of radioactive material and are therefore considered to be a potential source of corrosion which in turn could result in the spread of radioactivity, and ultimately to increased discharges to the environment. Specific measures have been taken within the SZC UK EPR^{TM} design to trap/contain as soon as possible any contamination that might be present in the various process circuits and to eliminate retention areas wherever practicably possible. Some examples of these design measures include:

- a failed fuel assembly fast detection system, which is an essential factor in limiting contamination of waste with alpha emitters, (further information on this system can be found in Argument 3);
- processing facilities (e.g. reactor coolant chemistry control and particulate filters) which limit both corrosion and deposits in the systems (further information on how the coolant chemistry is controlled to minimise corrosion can be found in Argument 5 and Sub Argument 6);
- the design of systems and tanks avoiding, as far as possible, vortex areas, undrained low points

even of a small volume (e.g. in valves), low velocity areas and dead cavities;

- the complete drainage of systems, facilitated by an adequate slope, as well as appropriate provision and positioning of drainage valves and vents;
- ventilation systems, designed according to segregated zones, to limit the spread of contamination, the minimisation of air ducts likely to transport contamination, the removal of contamination from as close as possible to its source, and the mounting of filters as far upstream as possible; and,
- the replacement of some concrete HVAC ducts with stainless steel in the Access Building (HW). The smoother surfaces reduce plating and so reduce the build-up of contamination in the HVAC system [Ref 88].

b) Evidence 69: Minimising the volume of contaminated liquid

480. Some required activities have the potential to result in uncontaminated water entering a contaminated water drain, and potentially picking up and spreading surface contamination. Although no additional radioactivity is produced, this would have the effect of increasing the volume of contaminated water requiring disposal.

481. Such activities include testing the spray deluge of the fire protection system during operation [Ref 89] [Ref 217]. The testing could result in additional water in controlled areas and greater volumes of water down contaminated drains. These activities, when planned in advance, should include a plan or BAT assessment to minimise the risk of contamination spread and the amount of water in controlled areas.

6.2.11 Claim 2, Argument 11: The liquid waste processing system is designed to have sufficient capacity and resilience to effectively treat all anticipated aqueous radioactive wastes

482. The TEU provides the abatement for non-recyclable spent liquid effluent prior to discharge to the environment via the KER or the TER with effluent arising from:

- primary coolant that cannot be recycled back to the primary circuit due to the presence of other impurities (chloride, sulphur, oil etc.) and effluents with low concentrations of boron that make recycling and recovery not practicable;
- effluents from the HN, reactor building and fuel building that are contaminated (chemical and radioactive contamination);
- potentially contaminated effluents from leaks of equipment carrying primary coolant and from floor washings, sumps installed in areas of the premises that contain equipment transporting primary coolant to collect this floor drainage;
- potentially contaminated effluents from leaks, floor washing and draining equipment (e.g. feed water), sumps are installed in controlled areas of the premises to collect this drainage; and,
- effluent produced outside the controlled area, which is normally uncontaminated and comes from leaks, floor washing and draining equipment.

483. These effluents are collected and routed through the Nuclear Vents and Drains System (RPE) which segregates at source and sends to the following tanks stored within the TEU;

- Process Drains Tanks containing the radiologically and chemically polluted primary coolant which are not recycled because they have a low boron content and may potentially have the wrong chemical properties or too much suspended material to be reused in the primary circuit.
- Chemical Drains Tanks containing active effluent more chemically polluted than the process drains.
- Floor Drains Tanks containing slightly radiologically and chemically contaminated effluent.

484. BAT demonstration for the TEU must include arguments and evidence showing the system has been suitably designed and sized to provide for the ongoing treatment of all anticipated aqueous radioactive wastes throughout the lifetime of the plant. The following sub-arguments and evidence demonstrate the SZC design offers sufficient resilience and capacity.

485. The TEU is not expected to treat effluent contaminated with oil which may be present due to decontamination of equipment or oil spilled inside the nuclear island buildings. The risk of oil is minimised at source and any effluent found to be contaminated with oil may be treated via mobile abatement plant or considered for alternative disposal.

6.2.12 Sub-Argument 9: The TEU is designed to treat the volume of radioactive effluents that could be expected to arise

486. The SZC TEU incorporates structures and operational practices designed for the volumes of aqueous radioactive wastes generated during the plant lifetime. This includes the design, sizing, number and operation of head tanks, provision of back-up storage capacity and operational methods using batch processing so allowing some flexibility in the abatement system.

a) Evidence 70: The head tanks are sufficiently sized to manage anticipated effluent arisings

487. SDM P3 [Ref 90] provides the sizing requirements of the TEU and its components. This confirms that the design provides 8 head tanks of the following configuration:

Table 6-2 Head tanks and sizing for SZC

Effluent	Configuration	Total Volume
Floor Drains	2 x 75m^3	150m^3
Process Drains	2 x 100m^3	200m^3
Chemical Drains	2 x 160m^3	320m^3
TEP Distillates	2 x 100m^3	200m^3

488. These tanks sizes are based on French OEF whereby the Process Drain tank total volume has been increased by 50m^3 to cope with the additional effluent during shutdown. This ensures that the tanks are sized such that their contents can be mixed and discharged in a time that is less than it takes for the other tanks to fill. Thereby, there is always a tank available to receive effluent.

489. A study [Ref 70] confirms that the expected volume of effluents over a sufficient period of time gives confidence that unplanned but not unexpected events can be accommodated by the sizing of the tank. In order to ensure sufficient head tank storage, studies [Ref 70] and [Ref 90] identified all systems that route to TEU. The studies used French OEF to confirm maximum expected annual volumes of effluents received by the TEU head tanks, considering both normal and unplanned (but not unexpected) events, such as long evaporator shutdown.

490. [Ref 90] describes the simulation model used to confirm that the tank volumes (as given in Table 6-2 above) are sufficient to cope with the volumes and contamination levels of effluent received by TEU taking into account tank volumes, tank inlet flow rate and duration of each treatment option.

491. Based on the assessment, [Ref 70] demonstrates that the TEU is sized for normal and reasonably foreseeable events, ensuring that effluent generated from two units and site buildings can be managed as appropriate whilst providing sufficient margins.

b) Evidence 71: There are sufficient number of head tanks

492. The total tank volume requirements are given in Evidence 68. This has demonstrated the total volumes provide storage capacity for effluent generated from two units, providing sufficient margins during other reasonably foreseeable events which includes the prolonged storage of effluent out of specification awaiting further treatment. As described in the system operation document [Ref 91], this volume has been subdivided, two tanks for each effluent route, and one tank is permanently available to receive the effluent from the units or site facilities. The other tank is either awaiting filling, or in the mixing and sampling processes, or under treatment, or in transfer to the KER. In addition, it is possible, via downstream pipework, to be able to send effluents back to an alternative storage tank should additional storage be required before any treatment process.

493. Fundamentally the time taken to treat effluent is less than the time taken to fill the current tanks (Evidence 70).

c) Evidence 72: Treatments work on a batch process and are not in continuous service allowing some flexibility of timing of each treatment

494. The total volumes of effluent expected for treatment in TEU are based on OEF and given in the system operation document [Ref 91] and the sizing document [Ref 90]. The study [Ref 70] considers other operational scenarios including during plant shutdown, increased RPE volumes/activities and extended evaporator shutdown, which may increase effluent volumes to the TEU head tanks. Taking into consideration these volumes, the tank sizing [Evidence 68] and number of tanks [Evidence 69] the following calculations demonstrate the flexibility and capacity to operate them on a batch process.

i. Process Drains

495. In normal operation expected volume is 1300m^3 per year [Ref 92]. Given the tank volume (100m^3) this would equate to 13 tank loads over the year. It is therefore anticipated to take approximately 28 days to fill one tank during normal operation.

496. The system sizing document [Ref 89] takes into consideration the annual volumes and potential flow rate variations and confirms the inlet flow rate into the process drains tanks could reach 0.9m^3/h. Based on this flow rate it can be considered that a single tank could, in exceptional circumstances take approximately 111 hours (4.63 days) to fill. As discussed in Evidence 68, the process drain tank total volume was increased for the UK EPR^{TM} by 50m^3 to provide additional margin of effluent flow variations.

ii. Chemical Drains

497. In normal operation the expected volume is 1700m^3 per year [Ref 92]. Given the tank volume (160m^3) this would equate to 10.6 tank loads over the year. It is therefore anticipated to take approximately 34 days to fill one tank during normal operation.

498. The system sizing document [Ref 89] takes into consideration the annual volumes and potential flow rate variations and confirms the inlet flow rate into the chemical drains tanks could reach 1.17m^3/h. Based on this flow rate it can be considered that a single tank could, in exceptional circumstances, take approximately 136 hours (5.7 days) to fill.

iii. Floor Drains

499. In normal operation expected volume is 7200m^3 per year [Ref 92]. Given the tank volume (75m^3) this would equate to 96 tank loads over the year. It is therefore anticipated to take approximately 3.8 days to fill one tank during normal operation.

500. The system sizing document [Ref 89] takes into consideration the annual volumes and potential flow rate variations and confirms the inlet flow rate into the floor drains tanks could reach 5m^3/h. Based on this flow rate it can be considered that a single tank could in exceptional circumstances take approximately 15 hours to fill.

iv. Treatment Timing

501. The report [Ref 70] confirms the following timing for each treatment option (allowing for sampling, analysis and treatment):

- Demineralisation takes approximately 48 hours once a batch is started.
- Evaporation process takes approximately 72 hours once a batch is started.
- Filtration takes approximately 24 hours once a batch is started.

v. Conclusion

502. During normal operation the floor drain head tanks are expected to be filled within 4 days and are sufficiently sized to enable the treatment of effluent via any treatment option as a tank batch process during normal operation. For process and chemical drain tanks during normal operation, the tank filling time is much longer allowing greater flexibility of effluent management.

503. During exceptional circumstances when the maximum flow rate is achieved there is still sufficient margin to treat process and chemical drains tanks once the tanks are full. There is the option however during exceptional circumstances [Evidence 71] to use the TER for additional capacity.

d) Evidence 73: There is additional back-up storage capacity that can be used to store effluents prior to treatment if equipment is out of service

504. EOS report [Ref 90] and the TER SDM [Ref 91] confirm that the TER storage tanks can also provide additional 2250m^3 buffer storage in the event the TEU head tanks are unavailable. The TER tanks are only expected to be used in exceptional circumstances and are not included in the justification of sizing report. Effluents in the TER tanks can be recirculated to enable sampling, can be sent to KER for discharge or sent directly from TER to TEU for further treatment.

505. Both TER and KER are able to transfer effluents back to TEU for further treatment prior to discharge. The number and sizing of the TER and KER storage tanks were assessed [Ref 93] [Ref 94] against predicted flow rates for operation when both units are at power (7.6m^3/h), when one unit is on planned shutdown (10.4m^3/h) and the unlikely event that one plant is on planned shutdown and the other unit is on unplanned shutdown (14.4m^3/h). The report [Ref 93] confirms that KER has sufficient capacity to receive TEU effluents during each operational configuration.

6.2.13 Sub-Argument 10: The TEU is designed to enable alternative means to manage radioactive waste to minimise discharges

506. The design of the SZC TEU has been optimised to include configuration of the system to enable diversion of effluent from head tanks for alternative treatment and for the treatment cycle to be managed to allow recycling of effluents, thus providing options for effluent abatement and ensuring minimisation of radioactive liquid discharges.

a) Evidence 74: The configuration of the TEU system allows alternative treatment of effluents from any head tank

507. The TEU offers three treatment options; filtration, evaporation and demineralisation. The logic is that floor drains will be treated by filtration, process drains by demineralisation, and chemical drains by evaporation. The design ensures that these three treatment options are available to all TEU effluents therefore not foreclosing any treatment options.

508. As stated in Section 2.4.1.1.4 of the TEU SDM P2 [Ref 91];

> *"After mixing and analysis, the effluents are sent for the most appropriate treatment depending on their characteristics; filtration, demineralisation or evaporation. The contents of the tanks are sent for treatment on the common line (by opening or closing pneumatic valves and by arranging the valves downstream of the pump in the desired configuration."*

509. The TEU piping and valve configuration means that effluent can be sent from the head tanks to any of the treatment options and effluent returned from filtration or demineralisation, which is returned to the head tanks, can be sent for further and alternative treatment, if necessary. Evidence 70 demonstrates that the system operates on a batch process and the fill/treatment rates do not foreclose any treatment option.

b) Evidence 75: The treatment cycle returns treated effluents to the head tanks that can then be retreated if needed

510. The primary filters and the resin beds are located on a recirculation loop returning treated effluent to the head tanks so that further treatment can be applied if required. This is demonstrated in the basic flow diagrams of the TEU SDM P2 [Ref 91] (and in the line drawing Figure 13 of [Ref 95]).

511. It should be noted that it is also possible via this route to send effluent from the chemical drains through the resin beds and return to the process drain head tanks to provide additional chemical drain storage.

512. Following treatment by the evaporator effluent is divided into two waste streams, concentrates and distillates. These are not returned to the head tanks but are sent to the appropriate downstream, the TES for concentrates and the KER for distillates. The distillates are only returned to the TEU head tanks from KER if further treatment of the distillates is required following sampling of the KER tanks.

6.2.14 Sub-Argument 11: The TEU design facilitates future operational flexibility

513. The design of the SZC TEU has been optimised to allow for operational flexibility. This includes:

- using a series of demineraliser beds to allow for isolation/bypassing of individual beds as required;
- use of multiple filters in drain lines and final pre-sentencing filters to minimise particulate discharge; and,
- recognises that filters and resin media will require replacing and disposal throughout the plant lifetime with systems in place to optimise replacement strategies, and so minimise solid waste generation whilst maintaining efficacy of the abatement system.

a) Evidence 76: There are 3 demineraliser beds which can operate in isolation enabling beds to be bypassed if needed

514. The TEU (see Figure 15 of [Ref 95]) comprises three demineraliser beds, which are located in sequence; however, the usage of beds is dependent on the chemical composition, as determined through analysis of the heads tanks. As effluents are returned to the head tank it is possible to select a bed to use for treatment, retest and, if required, pass through a different bed. If a demineraliser bed becomes unavailable, the bypass line ensures that effluent can still be sent through alternative beds.

515. The demineraliser beds are designed with a recirculation feed. This allows effluent to be retreated and therefore the specific sizing of the demineraliser tanks themselves has less impact on the system's ability to treat the anticipated activity and flows through the system. Additionally, the choice of resins will optimise the capacity of the system; the use of high capacity resins can be regenerated to optimise the continual performance of the beds.

b) Evidence 77: There are multiple filters in the system to trap particulate in each drain line as well as the final 5µm filter prior to sentencing to the KER

516. The TEU contains a number of filters (see Figure 10 of [Ref 95]), the porosity of each determined to be BAT in the EOS report [Ref 90]. In summary these include:

- initial 25µm filtration – located on the recirculation line, all head tanks are recirculated through this filter prior to further treatment, if required;
- 5µm final filtration on the discharge line used for all effluent;
- demineraliser upstream of the 5µm filter – used for the protection of the resin beds post pre-treatment stage 1; and,
- demineraliser downstream of the 25µm filter – used following demineralisation to catch resin fines.

517. The BAT assessment considered the proposals for filtration made at the UK EPR^{TM} GDA, compared to French fleet recommendations, and OPEX from Sizewell B. TEU receives effluents which in most cases have already been through a first stage of filtration. Therefore, filtration in TEU may not need to be as fine as in the upstream systems. Furthermore, effluents collected in RPE sumps and tanks e.g. floor drains are likely to contain larger particles therefore use of fine filters would generate disproportionate volumes of solid waste compared to the environmental gain provided by fine filtration. The TEU is designed to enable re-circulation of effluent through each treatment train thereby enabling the operator to determine the optimum treatment for each batch of treatment in order to optimise generation of solid waste and minimisation of liquid discharges. For these reasons using 25 µm filters in TEU for simple filtration, pre-treatment before demineralisation, evaporator protection and resin traps is considered BAT for SZC

518. Demineralisers are more vulnerable to particulate loading than evaporators, because they could become blocked and require premature replacement. Therefore, finer filtration is required upstream of demineralisers then upstream of the evaporator. For the reasons explained above, 5µm upstream of TEU demineralisers is considered BAT for SZC.

519. Final 5µm filtration is a regulatory requirement in France and is regarded as good practice for SZC to minimise discharge or particulate towards KER and TER. It is also consistent with Sizewell B practice. This represents an improvement compared to current French fleet practice because final filtration in the EPR^{TM} is provided by a separate filter located on the discharge line to KER/TER, whereas on the French fleet this is provided by filters also used for protection of the demineralisers or evaporator. Therefore, final 5µm filtration in TEU is BAT for SZC.

c) Evidence 78: Filters and resins are consumables which will be replaced during the lifetime of the plant and replacement will be optimised based on operational feedback

520. An EOS [Ref 90] recognises that resins are consumable items that will be replaced during the lifetime of the plant and their usage will therefore be kept under review. The initial resin choice has been justified in the EOS report as containing an anionic, cationic and mixed bed resin however the final selection will be based on the balance of working practices, process and techniques as employed across the extensive French, German and UK Sizewell B plants, considered to be directly relevant to the SZC design and other influencing factors. The final selection of resins for commissioning and then operation will be consistent with the findings of the EOS

report, the UK EPR^{TM} consumable chemicals' specification [Ref 96] and the Recommended Usage Guide for operating demineralisers in PWR plants [Ref 97].

521. The porosity of the filters has been justified for SZC [Ref 90]. The design of the filter housing means that it may be possible in the future to use filters of a different porosity if feedback from operation or developments in technology enables it.

6.2.15 Sub-Argument 12: The system and equipment is designed and specified to maximise its durability and enable maintenance and replacement of the plant

522. Consideration has been given to the SZC design to ensure materials selected are durable, access to and maintenance of plant is optimised and the design of structures and components known to require replacement though the lifetime of the plant are optimised for ease of replacement. These factors help to minimise the generation of solid waste and optimise the management and disposal of waste over the lifetime of the plant.

a) Evidence 79: The materials used in the system are designed to be durable

523. In order to contain the radioactive material, prevent leaks and limit radioactive discharges into the environment, all parts of the TEU including piping, valves and other components exposed to the effluent must be made from austenitic steel, except for components routinely exposed to high temperatures or chemical concentrations.

524. The base material for TEU equipment is 304L stainless steel, however, the reagent injection system must be made from 316L stainless steel that is resistant to acid and concentrated sodium hydroxide. Parts of the evaporation unit in contact with concentrates or effluent at a higher temperature (above 80ºC) will be manufactured from materials that have a greater corrosion resistance at higher temperatures under high chloride conditions [Ref 92].

525. Non-replaceable equipment within the TEU unit shall be designed for a lifetime of 60 years. This includes the TEU head tanks and demineraliser beds. The data sheets [Ref 98] for this equipment specifies a life span target of 60 years and a design requirement of corrosion allowance of 0.5mm. The shell, head and internal material of the TEU tanks and beds is stainless steel. This will be subject to supplier feedback and the final design will be justified in the suppliers EDS document which will become an identified reference in the SZC Environment Case.

526. The TEU evaporator was previously a non-replaceable component located in the HQB building. Evidence from FA3 has demonstrated that the TEU evaporator sub-system made from stainless steel will be subject to corrosion due to the presence of chlorides. The final choice of material for the evaporator is subject to further feedback and has not been guaranteed for 60 years. In order to ensure the evaporator availability, modification to the building has been proposed to enable its replacement, see Evidence 79 for further detail.

b) Evidence 80: The equipment is accessible to allow inspection and maintenance

527. All parts of the TEU including piping, valves and other components exposed to the effluent have welded connections to minimise the risk of leakage except where flanged connections are required to facilitate equipment removal for inspection, maintenance or testing [Ref 92].

528. The accessibility, in service inspection and maintenance of equipment has been taken into consideration in the system and HQB design:

- The head storage tanks, demineralisers, filters, pumps and evaporation unit are separated by biological shielding (material included in design to adsorb radiation).
- No valves or measuring equipment are installed inside the shielded compartment of the evaporation column.

- Access is controlled to ensure worker safety for radiation protection purpose.

c) Evidence 81: Equipment/components that could wear out is replaceable

529. Non-replaceable equipment within the TEU unit shall be designed for a lifetime of 60 years. The TEU evaporator was previously a non-replaceable component located in the HQB building. Evidence from FA3 has demonstrated that the TEU evaporator sub-system made from stainless steel will be subject to corrosion due to the presence of chlorides. Further supplier feedback indicated that the material choice could not be guaranteed for a lifetime of 60 years. It has been demonstrated [Ref 99] that the BAT/ALARP solution is to modify the HQB building to feature a removable ceiling, which will enable the removal and replacement of the evaporator unit.

6.2.16 Sub-Argument 13: The system is designed with sufficient sampling and monitoring to enable appropriate management of radioactive waste

530. Sampling and monitoring of effluents is undertaken both in-process for optimising treatment processes and for final discharge sentencing. The TEU monitoring system has been designed to ensure appropriate monitoring, sampling and analysis is carried out to support these functions. This is demonstrated through the use of in-process monitoring to optimise the treatment, sampling and monitoring of the process prior to abatement in the head tanks and post treatment to ensure compliance with KER tanks acceptability criteria.

a) Evidence 82: Sampling of head tanks prior to start of treatment to ensure the optimum treatment method available is used

531. The TEU head tanks are analysed following a process of recirculation and this enables selection of the most appropriate treatment. All effluent is treated by initial filtration prior to sampling and these filters are provided on each recirculation line.

532. A sampling line, which is part of the Effluent Treatment Building Sampling System (TEN), is connected to this recirculation line and once the tanks contents have been mixed the operator is able to take a sample via a sampling glovebox which is then analysed in the laboratory (see Figure 4 of [Ref 95]).

533. The time taken for mixing and sampling is taken into account for the sizing and batch operation of the system [Evidence 70].

b) Evidence 83: Treated effluent is monitored prior to sentencing to the KER tanks to ensure it meets the relevant criteria

534. Following treatment by filtration or demineralisation, effluent is returned to the head tanks in TEU. Following the same process as given for treatment selection, the operator is able to take samples from the head tanks to determine the quality of effluent prior to discharge to the KER.

535. Following treatment by the evaporator, distillates are not returned to the head tank, and are directed towards the KER. This discharge line is equipped with an automatic activity detector, preventing unsuitable effluent from being sent to the KER; instead the effluent recirculates around the evaporator loop.

c) Evidence 84: Effluent is sampled in the KER tanks prior to discharge to ensure it meets the specification

536. There are three KER tanks located in the HXA building. The tanks are equipped with a recirculation line which is supported by a TEN sampling line and connected to a sampling sink in the HXA building. Effluent can also be recirculated back to TEU head tanks for recirculation, sampling and further treatment if required [Evidence 71]. The final threshold for discharge from KER will be determined as part of the operational specifications, however, the discharge line also features an activity monitor to ensure that erroneous discharges do not occur.

d) Evidence 85: In-process monitoring is in place to check the effectiveness of the abatement equipment

537. The TEU features the following efficiency monitoring provisions.

i. Effectiveness of Filters

538. The ability to monitor differential pressure across the filter is a requirement of HPC RC1.2. Based on the HPC RC1.2 system requirements, the P2 [Ref 91] requires that the filter is changed when this exceeds 2.5bar, or when the filter has reached its 5-year design life however these requirements are subject to supplier feedback.

539. Following treatment by filtration effluent is returned to the head tanks in TEU. Following the same process as given for treatment selection, the operator is able to take samples from the head tanks to determine the quality of effluent prior to discharge to KER and this can also be used to verify that filters are working.

ii. Effectiveness of Demineralisation

540. TEN sampling lines are located after each of the demineraliser beds so that the performance of individual beds can be assessed. In addition, effluent is returned to the head tanks in TEU and the operator is able to take samples from the head tanks to determine the quality of effluent prior to discharge to KER and this can also be used to verify the effectiveness of the demineraliser beds.

iii. Effectiveness of Evaporation

541. During warm up of the evaporator, the activity of distillates is monitored by an online gamma monitor which is part of the KRT. Once the threshold for effluent quality has been achieved, the distillates are then discharged to KER. The discharge line to KER is equipped with an automatic activity detector which monitors the effectiveness of the evaporator and prevents unsuitable effluent being sent to KER. The TEU distillates line is also equipped with a proportional flow sampler which takes a composite sample for laboratory analysis in order to determine the efficiency of the evaporator and the contribution of TEU distillates in the final discharge.

6.2.17 Sub-Argument 14: The totality of the effluent management systems in the UK EPR^{TM} support the delivery of the TEU Environment Protection Function

542. The design of the UK EPR^{TM} and the integration of the TEU ensure that effluent is managed both prior to transfer to the TEU for abatement (to ensure it minimises any burden on the abatement system) and, that effluent prior to discharge can be returned to the TEU for further processing in the event sampling in the KER/TER discharge tanks shows more treatment is required to minimise impact on the environment from the discharge and ensure RSR permit compliance.

a) Evidence 86: Upstream systems include abatement close to the point of waste generation to minimise the demand on the TEU

543. TEU receives effluents which in most cases have already been through a first stage of filtration close to the source such as RCV, PTR and RPE which employ filtration as fine as 1µm. The filter porosity within these upstream systems was assessed through the EOS1 work to demonstrate the design was optimised. Systems such as RCV and TEP also provide upstream abatement by demineralisation to reduce soluble radioactivity.

544. The filtration of effluent upstream of TEU ensures that the demand of the TEU is minimised such that final treatment in TEU can be optimised to minimise discharges and solid waste generation.

b) Evidence 87: There is the ability to return out of spec effluents sentenced to KER/TER for retreatment in the TEU

545. Both TER and KER are able to transfer effluents back to TEU for further treatment prior to discharge. The number and sizing of the TER and KER storage tanks was assessed and the report [Ref 94] confirms that KER has sufficient capacity to receive TEU effluents during any operational configuration. In addition, effluent is transferred back to the TEU head tanks if further treatment is required [Evidence 69] and in the case of evaporator distillates, effluent can be diverted from the holdup tank back to the head tank without being sent to KER.

6.2.18 Claim 2, Argument 12: Minimisation by the management and abatement of radioactive aqueous effluents

546. The UK EPR^{TM} incorporates a number of improvements to filtration, demineralisation and evaporation techniques for treatment of radioactive liquid effluents.

547. SZC employs management and abatement techniques of the liquid effluents generated through operation of the plant and systems. Liquid effluents generated are all appropriately segregated and abated depending on their source and radiochemical contents. Dedicated treatment systems are designed to minimise the activity and volume of each effluent stream.

548. The systems and processes used for control and abatement of liquid effluents and their role in minimising discharges of radioactivity to the environment are detailed in the following sub arguments:

- Ion exchange of liquid effluents [Sub Argument 15]. Information is presented on the key aspects of ion exchange (demineralisation) usage in minimising the amount of radioactivity discharged in liquid effluents from SZC.
- Selection of ion exchange resins [Sub Argument 16]. The selection of ion exchange resins within the UK EPR^{TM} design will take into account the removal rates of soluble activity, maximise effectiveness, and minimise the amount of radioactivity discharged or disposed of to the environment.
- Evaporation of liquid effluent [Sub Argument 17]. To minimise the amount of radioactivity discharged to the environment at SZC evaporation will be applied to the primary coolant for recycling in the primary circuit and non-recycled liquid effluents from the primary circuit. It is a technique mainly used on effluents containing significant contamination and is used after pre-treatment of the effluent by other techniques such as filtration and demineralisation.
- Filtration of liquid effluents [Sub Argument 18]. Filtration is used to minimise discharges of radioactivity in particulate form to the environment. The overall approach to the design and selection of filtration for the treatment of liquid effluents is based on OEF from a significant body of national and international knowledge and optimisation of the selection of filters.
- Segregation of liquid effluent streams [Sub Argument 19]. Segregation is an important contributor to minimising the amount of radioactivity discharged to the environment, in part by ensuring that where practicable effluents can be recycled and also by enabling more effective treatment of effluents to remove radioactivity.
- Decay storage of liquid effluents [Sub Argument 20]. This takes advantage of the radioactive decay of short-lived radionuclides by storing effluents for a sufficient period of time to reduce the total amount of radioactivity discharged into the environment.
- Control of spent fuel storage pool water [Sub Argument 21]. Control of key parameters (pool water temperature and chemistry) is used to ensure the integrity of fuel cladding during periods of

storage. This will ensure that the radioactivity remains inside the fuel, rather than escaping and being discharged or disposed of to the environment in solid, liquid or gaseous wastes.

549. The demonstration of BAT for the minimisation of radioactivity in liquid effluent discharges by abatement is demonstrated by use of the techniques described in the sub arguments.

6.2.19 Sub-Argument 15: Ion Exchange of Liquid Effluents

550. The SZC Permit application head document [Ref 1] provides information on the systems present in the UK EPR^{TM} units and their roles in operating the reactor and in the management of radioactive wastes. The importance of the control of primary coolant chemistry was discussed under Claim 1, Argument 5. This is achieved by the RCV and the REA which together control the volume and chemical composition of primary coolant, using information provided by the REN.

551. A proportion of primary coolant (referred to as let-down) is continuously routed through the RCV where it is purified using filters and demineralisers, where boron and other chemical reagents (e.g. lithium compounds) needed to achieve primary coolant chemistry control are added to provide continuous clean-up of the RCP and to ensure that the primary coolant chemistry is optimised for all phases of reactor operations. The proportion of primary coolant recycled this way varies across the fuel cycle.

552. Filtration removes insoluble materials from the primary coolant or other effluent streams and is discussed under Claim 2, Sub argument 18. Demineralisation (also known as ion exchange) removes soluble materials from aqueous streams. The process of demineralisation is the removal of soluble salts (substances present in ionic form) from aqueous effluents using ion exchange resins which retain certain substances which are then converted into solid waste when the demineralisation medium is spent. This process is widely used throughout the nuclear industry and many other industrial sectors. In the UK EPR^{TM} demineralisation is used not only for the treatment of primary coolant which is recycled but also in the treatment of water from the spent fuel pools, of a range of non-recycled liquid effluents including spent primary circuit effluents from various drainage systems and SG blowdown effluent arising from the secondary circuit.

553. Demineralisation is used for the control of the concentration of a number of chemical components, including lithium, in operation of the UK EPR^{TM}. In addition, a significant proportion of the radioactive contamination that is generated in the reactor cores of nuclear power stations first leaves the reactor core in solution within the primary coolant. Some of these radionuclides come out of solution in the reduced pressure of the primary coolant treatment systems, but others remain in solution. Some of the soluble radionuclides typically present in this type of effluent have the potential to give rise to significant radiation doses because of their chemical and physical properties and their behaviour in the environment. Treatment is therefore nearly always required prior to minimise the amount of soluble radionuclides discharged into the environment and to ensure that these radionuclides are removed from the primary circuit where they could cause damage to the reactor's components through corrosion and deposition processes Radioactive decay of short-lived isotopes of iodine also takes place during the removal of iodine-containing species from liquid effluent by demineralisation, a process which also contributes to the reduction of discharges of iodine to the environment.

554. Treatment options centre on either taking the contamination out of solution or concentrating it significantly in either liquid or solid forms to facilitate storage/further processing. Use of ion exchange resins is one of these treatment options. Ion exchange resins are recognised as industry standard practice for the removal of soluble radionuclides and are used extensively on nuclear power stations in the UK and internationally. In its Decision Document on the British Energy Generation Limited RSA93 Authorisations (December 2006) [Ref 99], the Environment Agency indicated acceptance of the British Energy Generation Ltd (BEGL) claim that ion exchange resins represented the best treatment option for soluble radioactivity. In its GDA Public Consultation Document on the UK EPR^{TM} [Ref 100], the Environment Agency stated that "at this time, filtration by cartridge filter, ion exchange and, for effluents incompatible with ion exchange, evaporation is BAT for use in the UK EPR^{TM}." For SZC there have been no new tried and tested abatement techniques that can replace the use of resins and

therefore SZC will continue to use demineralisation as one of a number of available treatment options given its historic and continued use in the UK.

555. Information is presented on the following key aspects of the use of ion exchange resins in minimising the amount of radioactivity discharged in liquid effluents from SZC:

- Removal of soluble fission and activation products and small amounts of carbon-14 from solution. In the nuclear industry ion exchange resins are typically used to remove the following materials from effluent streams:
    - soluble fission products originating from releases through small defects in the fuel rod cladding (e.g. caesium isotopes, iodine isotopes);
    - soluble corrosion products released by the primary system internal structures and activated as they pass through the reactor core (e.g. cobalt-58, cobalt-60, manganese-54);
    - nickel, zinc carbonates and impurities such as calcium and aluminium; and,
    - in addition to the above, the ion exchange resins also capture small quantities of carbon-14.

556. At nuclear power plants, ion exchange resin beds are normally used in combination with other techniques, typically including some form of particulate filtration. On the UK EPR^{TM}, ion exchange resins are used in the following systems:

- The TEP; two mixed-bed demineralisers containing resins are fitted between the two sets of filters and are dedicated to the processing of the primary circuit liquid effluent, which is considered “recyclable” effluent. Further information on the use of ion exchange resins in this system is presented below in Evidence 87.
- The TEU; in terms of the ion exchange units three different types are employed to optimise removal of ions from the effluents:
    - strong high-capacity gel-type cationic resins which have a large exchange capacity;
    - strong high-capacity anionic or macro-porous resins which retain large molecules and colloids and allows for increased exchange rates when necessary; and,
    - mixed-bed-type.

557. Further information on the use of ion exchange resins in this system is presented in Evidence 88:

- The APG; this system includes filtration and ion exchangers. It is used exclusively to treat blowdown water before it is recycled to the system. Further information on the use of ion exchange in the APG is presented in the Evidence 89.
- The PTR; This system includes filtration and ion exchangers. It is used to purify the water used in the various pools within the UK EPRTM. Further information on the use of ion exchange in the PTR is presented in Evidence 90.

558. In all these locations the ion exchange resins form key functional elements of flexible treatment systems that can be operated to treat the specific characteristics of the various waste streams. Information on the selection of ion exchange resins is presented in Sub Argument 16.

559. Demineralisation systems are designed with a recirculation feed. This allows effluent waste streams to be retreated if required. The specific sizing of the demineraliser tanks is therefore less sensitive to the anticipated activity and through flows due to this feature.

560. The reference case for size and use of demineralisers is based on a BAT assessment that has been undertaken for the GDA to demonstrate that the filtration and demineralisation system specifications proposed for the UK EPR^{TM} in the TEP, TEU and APG represent BAT for minimising radioactive waste generation. The functional requirements of effluent treatment systems that include demineralisation beds and selection of demineralisation media are defined at the design stage. However, the specification of resin media and plant operating configurations will evolve with operational experience, depending on the flexibility of the overall plant design.

a) Evidence 88: Removal of soluble fission and activation products and small amounts of carbon-14 from solution

561. The UK EPR^{TM} will be operated so that discharges of carbon-14 are preferentially discharged to atmosphere by reactor degassing, which is considered as BAT [Ref 5].

562. Chemical speciation studies analysed by EPRI [Ref 59] show carbon-14 in the primary coolant of PWR stations is predominantly (58 to 95 %) in organic form.

563. Very little is known of the behaviour of the organic carbon-14 species during the clean-up of reactor coolant. However, the chemical speciation of carbon-14 on primary demineralisation resins from PWRs also shows predominantly organic forms (72-92 %). The attachment mode of these organic carbon-14 species on the resin is unknown, but probably occurs by some type of sorption process rather than by a normal ion exchange mechanism or by microfiltration for colloidal forms [Ref 5]. The primary technique for minimising cobalt-60 and cobalt-58 disposals and discharges are through operation of the reactor purification plant (RCV), which includes filtration and ion exchange systems. The operation of the boron recycling system is also effective for removing corrosion products from primary coolant let-down, which are polished on a specific ion exchange bed. These techniques minimise the specific activity of the primary coolant, a very minor proportion of which is transferred to the secondary liquid effluent treatment systems through managed let-down and minor leakage. Purification of primary coolant does not, however, achieve complete decontamination and removal of corrosion products, although high decontamination factors can be achieved. Cobalt-60 and cobalt-58, amongst other corrosion products, are normally present in low concentrations in primary coolant let-down to the liquid radioactive waste effluent treatment system, where further purification is undertaken by a combination of evaporation, ion exchange or filtration [Ref 5].

564. The objective is, therefore, to ensure that cobalt-60 and cobalt-58, amongst other corrosion products, are removed from liquid effluent at source and concentrated into solid waste by-products such as ILW and Low Level Waste (LLW) spent filters, spent ion exchange resins and evaporator concentrates from primary coolant and secondary effluent treatment. Cobalt-60 is a targeted radionuclide for abatement in liquid and gaseous effluents as it is a relatively significant contributor to public dose compared to other particulate activated corrosion products. Due to its half-life of 5.27 years, cobalt-60 in solid waste is retained long enough to allow sufficient decay. If the solid waste is incinerated, cobalt would be either retained in the ash or transferred to the abatement plant secondary solid waste. Therefore, the overall radiological impact of cobalt-60 in solid waste is lower than the impact of the environmental discharge of liquid and gaseous effluents. Cobalt-58, which has a much lower radiological significance, is minimised as a consequence of cobalt-60 abatement. Targeted abatement represents the BAT and is consistent with the concentrate and contain principle, provided that the solid waste volumes produced are not excessive. This is achieved through optimisation of the abatement process and implementation of best practice. These are matters for the plant operator. The GDA submission states that the UK EPR^{TM} allows maximum flexibility with regard to meeting expectations for the demonstration of BAT. Depending on decisions made by the prospective licensee in the UK, the UK EPR^{TM} is capable of

achieving very low radioactive liquid discharges for cobalt-60 and cobalt-58 (as demonstrated by current French PWRs) [Ref 5].

565. A modified chemistry regime (reduced pH) will be implemented on the UK EPR^{TM} prior to refuelling upon shutdown, the primary purpose of which is to remove corrosion products from in-circuit and fuel cladding surfaces. This measure will primarily reduce worker doses. This standard practice reduces the radioactive source term by avoidance of further corrosion product activation and minimising the potential for fuel cladding corrosion and consequent leakage into the primary circuit. The main stages to achieve these objectives involve reducing pH by removal of lithium in addition to forced oxygenation through introduction of hydrogen peroxide followed by high-flow rate decontamination in the RCV.

566. After refuelling, primary coolant must be degassed and purified to reduce impurities such as dissolved oxygen and nickel to low concentrations, which are specified according to requirements [Ref 5].

b) Evidence 89: The Coolant Storage and Treatment System

567. The primary coolant is subjected to the following successive purification stages:

- Filtration upstream of the TEP by the RCV.
- Fine mechanical filtration using two redundant filters to retain fine insoluble particles with a 99.8 % efficiency.
- Ion exchange resin treatment, to retain soluble species.
- Mechanical resin trap, to retain resin fines which may not be captured by the duty demineraliser strainer.

568. A BAT report [Ref 90] demonstrates that the demineralisation media represent the BAT for the SZC design. For TEP the downstream demineralisation filter is justified as 5µm.

569. A proportion of carbon-14 is contained in the primary liquid effluents which may be retained on filters and ion exchange resins before the TEP, thereby giving rise to solid wastes [Ref 5].

570. Where carbon-14 is present in liquid effluents it is reduced by demineralisation, but it is not a targeted nuclide as the potential discharges are not as radiologically significant as others such as radio-isotopes of caesium and cobalt.

c) Evidence 90: The Liquid Waste Processing System

571. The TEU has a highly flexible arrangement that will enable bespoke treatment arrangements for particular effluent streams depending on the characteristics of the effluent.

572. The system receives effluents, as described in Argument 11, from process drains, chemical drains and floor drains. A BAT report [Ref 90] demonstrates that the demineralisation media represent the BAT for the SZC design.

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

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

574. There are two successive stages in the demineralisation operation:

- Firstly, recirculation: the spent effluent processed in the demineralisers is sent back to the front tank from where it came.
- Secondly, in open circuit: when the activity has been controlled, the treated spent effluent is sent to for monitoring and discharge (KER tanks).

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

576. After being treated in the evaporator (TEU), the LLW and very low level waste (VLLW) concentrates are normally transferred to the TES in order to be conditioned for safe transport and storage off-site. A return line has been added from the TES tanks to the TEU evaporator in order to be re-concentrated. This allows any of the concentrates drained from the TEU to TES to be returned to the TEU evaporator if the physical and chemical criterions (boron concentration) for transport of normal conditions are not met.

577. A BAT assessment [Ref 70] demonstrates that the TEU has sufficient capacity and resilience (for example, in case of outage due to maintenance or breakdown) to cope with all the aqueous radioactive waste arising and to ensure that the use of the TEU evaporator is optimised.

578. The design change CFSE0230 'Modification of the maximum allowable working pressure in the TEU demineralisers' [Ref 101] was reviewed for its environmental impact and determined that the design change could have the potential to impact the containment function of the TEU demineralisers but would not impact its abatement function. This design change updated the maximum pressure of the demineraliser units following an assessment of pressure losses in the system. The impact on the demineralisers was confirmed to be very low and the need for a BAT justification of the change was superseded by the requirement for the supplier of the demineraliser units to produce an EDS to demonstrate that the final design meets the specification and the containment function will be provided [Ref 102].

579. There are no further significant changes that impact the design of the TEU demineraliser units. The sizing of the TEU document [Ref 90] provides the technical data for the demineraliser units and confirms that the gross volume of each unit is 3.93m^3 with the volume of resins expected to be 2.1m^3. This volume of resins has been evaluated [Ref 103] and through the use of hydraulic calculations confirms that sizing of the demineraliser units is appropriate to optimise performance given the expected operating conditions (temperature, flow rate and nature of the resin).

d) Evidence 91: Liquid effluent processing in the Steam Generator Blowdown System

580. The blowdown from the SGs is processed by the APG. This circuit is specific to each UK EPR^{TM} unit and is intended to purify the blowdown water before it is recycled in the secondary circuit.

581. The purification plant for the SG blowdown comprises:

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

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

583. The inactive resins from the APG are transferred to the TES for treatment. The original design included one 'bigbag' tank, however a second tank has been added to the design in order to streamline the treatment process of inactive APG resin handling, by having two tanks operating simultaneously [Ref 66].

e) Evidence 92: The pool water treatment system (PTR)

584. Treatment systems for water in the Fuel Building spent fuel pool will incorporate ion exchangers and filters. The ion exchangers will help to maintain the chemical and radiochemical purity of the pool water by removing dissolved ions. The filters capture any particulate matter that comes from corrosion products on fuel stored in the fuel pool.

585. Pool-water treatment system comprises one purification circuit for the spent-fuel pool, one purification circuit for the reactor building pool and the IRWST pool, and skimming circuits for the spent-fuel and reactor building pools (one skimming circuit per pool). The system comprises two cartridge filters, a demineraliser and a filter (for trapping resins) used to purify the pool water. There is an additional cartridge filter in the skimming circuit for the spent-fuel pool. The PTR filters have been substantiated in a BAT assessment [Ref 90].

6.2.20 Sub-Argument 16: Selection of Ion Exchange Resins

586. The selection of ion exchange resins within the UK EPR^{TM} design will take into account the removal rates of soluble activity which will maximise effectiveness and minimise the amount of radioactivity discharged or disposed of to the environment.

587. The type of resins selected in order to efficiently perform demineralisation is largely dependent on the radioactive effluent which is undergoing treatment. In addition, a number of resins of differing types are used for certain treatments, such as the process drain, in order to optimise the removal of ions from the effluent.

588. The media used in the UK EPR^{TM}, and the use of ion exchange resins for the demineralisation process is an approved technique in the UK. In particular, these techniques are considered as BAT in light of the recommendations of the Nuclear Energy Agency [Ref 103] and the IAEA [Ref 104]. More detailed information on the type and quantity of resins is provided in [Evidence 92].

589. The selection of ion exchange resins for SZC therefore significantly influences the efficiency of removing radioactivity from the liquid effluent within the liquid effluent treatment system. The resins selected within the UK EPR^{TM} design are considered BAT in ensuring that radioactivity discharged or disposed of to the environment following the ion exchange process will be minimised. It is important to note that the selection and mode of use of ion exchange resins will be optimised during operations and will take account of OEF not only at SZC but also other EDF nuclear power stations and broader international experience [Evidence 91].

590. Experience from the operation of the waste treatment systems at Flamanville 3 which use the same design will be applied to the UK EPR^{TM}s at SZC as part of the ongoing optimisation process.

591. The design of the liquid effluent treatment systems is sufficiently flexible to allow selection of the most adequate ion exchange media at the right time. Ion exchange media are consumables and the type of media used in the treatment systems might be adapted throughout the operational life of the plant in order to continuously apply BAT.

592. An EOS [Ref 90] (referred to in the report demonstrating the close out of HPC IC10 from the HPC RSR permit application [Ref 105]) followed a process of identifying OEF and influencing criteria that would ensure maximum environmental benefit without incurring excessive costs and concluded that the choice of resin bed media for TEU demineralisers are BAT on the basis that:

- the design does not foreclose options;
- the resins are consumables that can be replaced during the lifetime of the plant, providing the ability to take advantage of new developments should they arise; and,
- OEF from high performing plants show comparable demineraliser design noting the differences in system design.

593. This will be subject to commissioning tests and future developments in technology. However, it is expected that any deviations from this report will follow the design change process and will be assessed to demonstrate BAT.

594. The use of consumables (filters and resins) can be optimised throughout the lifetime of the plant. The current specification of these will be used for procurement and for the commissioning of SZC, at which point OEF from FA3 and the commissioning process will determine if further optimisations are needed.

a) Evidence 93: Type of Ion Exchange Resins

595. A wide range of exchange media are available for use in this application. The materials are available in a variety of forms whose chemical and physical properties can vary widely. The media can be naturally occurring or synthetic, organic or inorganic.

596. Examples of naturally occurring inorganic ion exchange materials include clays (e.g. bentonite, kaolinite and illite), vermiculite and zeolites (e.g. analcite, chabazite, sodalite and clinoptilolite). Naturally occurring organic materials that exhibit ion exchange behaviour include polysaccharides (such as cellulose, algic acid, straw and peat), proteins (such as casein, keratin and collagen) and carbonaceous materials (such as charcoals, lignites and coals). The key advantage of synthetic ion exchange materials is that they can be created with the desired physical and chemical properties [Ref 5] and hence tailored to specific applications. Example synthetic inorganic materials include zeolite, titanates and silico-titanates. However, the largest group of ion exchangers, and the most frequently used in nuclear power applications are the synthetic organic ion exchangers. This group includes polystyrene, divinyl benzene, phenolic and acrylic resins. Synthetic organic resins are the predominant type of ion exchange resin now in use.

597. The ion exchange medium chosen depends on the properties of the target ion, the presence of other competing ions in the feed stream, availability and cost. The capacity of the media relates to how much target ion a particular medium can hold. The ion exchange media may be changed by hydraulic means or be held in removable cartridges [Ref 106].

598. Ion exchange media usually implemented in UK nuclear installations and in the UK EPR^{TM} are either made of:

- organic resins, which can carry various functional groups that provide a cation or anion exchange effect; or,
- inorganic ion exchangers, some of which act as adsorbers rather than ion exchangers and, to make them more efficient, are fabricated into beads or microporous gels with a high surface area.

599. The choice of demineralisation media represents a compromise between three factors:

- The overall type of wastes to be treated – some waste streams have a specific composition which allows a particular demineralisation medium to be used at maximum efficiency. However, in other cases the composition of the waste stream and its variability require a more general-purpose demineralisation medium to be used.
- The nature of the nuclide to be removed – if a specific nuclide is to be removed from the waste stream, a specialised demineralisation medium can be chosen. However, if a more general clean-up is required a medium that offers an overall good performance needs to be used (e.g. incorporating anion and cation beds).
- The quantities of secondary waste arisings – a demineralisation medium might offer a good selectivity for a particular radionuclide or waste stream but may have a short lifetime, so resulting in higher secondary solid waste arisings.

600. For the treatment of radioactive process liquids and selection of an optimised medium, the most important measures of system performance are selectivity and ion exchange capacity. The decrease in achievable

decontamination factor is a relative notion. All ionic species in liquid effluent are in competition with each other to absorb inside the demineralisation bed. Hence, a decrease in efficiency for a particular species may be associated to an increase in efficiency for another one. Also, some species will have an impact on the pH of the treated fluid, whereas some species will have an impact on the redox potential of the fluid. As a consequence, these species may lead to changes in chemical forms and/or valences of other elements. Taking all of these into account, these species could be said to lead to a 'change of efficiency' of the demineralisation medium. The decrease in the decontamination factor of a demineralisation system over time and the associated appearance of the active species in the treated liquid dictates the requirements for renewal or regeneration of the demineralisation medium.

601. The process drains (active effluent, chemically clean, aerated and borated) are treated by standard demineralisers in the TEU. Three types of resins can be used to optimise removal of ions from the effluents:

- Strong high-capacity gel-type cationic resins which have a large exchange capacity.
- Strong high-capacity anionic or macro-porous resins which retain large molecules and colloids and allows for increased exchange rates when necessary.
- Mixed-bed-type.

602. An EOS [Ref 90] (referred to in the report demonstrating the close out HPC IC10 from the HPC RSR permit application [Ref 105]) showed that this three bed configuration is BAT as it allows for optimisation of the radionuclides targeted by varying the resins used over the three beds as well as providing a sufficient level of back up in the third mixed bed. This sizing is based on design successfully employed at N4 plants in France and gives the ability to recirculate effluents to enable a sufficient level of decontamination prior to discharge (or a decision to use alternative treatment techniques). The addition of more beds would provide some additional redundancy as well as flexibility, however, this benefit is considered disproportional to the impacts which include an increase in space requirements and an increased operator burden and dose due to increased maintenance requirements.

603. In addition to the number of beds and resin type, the physical properties may further optimise the demineralisation process. Anion resins may be strongly or weakly basic (alkaline). Strongly base anion resins (quaternary ammonium type in hydroxylated form (OH^-)) maintain their charge across a wide pH range and offer good resistance up to 60ºC, whereas weak base anion resins can be neutralised and lose charge through deprotonation. Weak base anion resins, however, provide greater mechanical and chemical stability.

604. Cation resins may be strongly or weakly acidic. Strongly acidic cation resins (sulfonated polystyrene type in hydrogenated (H^+) form) maintain their charge across a wide pH range and resist temperatures up to 120ºC whereas weakly acidic cation resins have the benefit of being easily regenerated with strong acid [Ref 28].

605. Given that the resins are consumables and in order to optimise the final specification, the detailed specification including these physical properties of resins will not be confirmed until closer to commissioning. This will feed into the SZC Environment Case and will continue to be reviewed throughout the lifetime of the plant.

606. The EOS recognises that resins are consumable items that will be replaced during the lifetime of the plant and will therefore be kept under review however the initial design should be based on the balance of working practices, process and techniques as employed across the extensive French, German and UK Sizewell B plants

b) Evidence 94: Ion Exchange Process Operational Experience Feedback

607. The designs for the UK EPR^{TM} TEP, TEU and APG have evolved from significant OEF, particularly in France and Germany. The designs have been developed by AREVA and EDF and predecessor organisations, evolving from the following reactors: French N4 and 1300 MW; the West German KONVOI; French 900 MW and its US designed predecessor at Chooz-A.

608. The safety of the 58 PWR units in France is regulated by the French Nuclear Safety Authority, who, together with respective local government for each site, provides EDF with a site licence to dispose of radioactive waste. The legislation supporting the licence requires the use of BAT to ensure waste generation and discharges are minimised. The requirements for application of BAT are consistent with the requirements for BAT in England, as defined by the EA.

609. A common operating strategy for ion exchange at PWRs is to use a cation bed for lithium removal, a lithiated mixed bed for clean-up at power and a hydrogen form bed for clean-up during shutdowns. OEF in France allows recommendation of resins with high divinylbenzine content in systems where circuit conditions are severe (i.e. high flow rate, oxidising environment, high irradiation exposure). Gel-type resins with high retention capacity are recommended when the expected performance of the demineraliser relies on its total capacity [Ref 97].

610. Experience from the French fleet also shows that the performance of the TEU has achieved decontamination factors in the region of 1,200. This is based on a system similar to that used on the UK EPR^{TM}. The Environment Agencies Requirements Working Group (EARWG) presents data for efficiency of ion exchange systems with an expected range of 10 - 1,000 for decontamination factors. Therefore, it is considered that this OEF demonstrates that the setup used in the French fleet, similar to the UK EPR^{TM}, offers a good level of protection. Experience from the French fleet has shown abatement efficiencies in the order of 99.9 % can be achieved across the fleet using similar systems [Ref 107].

611. As shown in an EOS [Ref 90] (referred to in the report demonstrating the close out of HPC IC10 from the HPC RSR permit application [Ref 105]), the demineraliser units themselves are designed to be constructed of stainless steel and each capable of holding anionic, cationic or mixed resins [Ref 59]. Each unit is also fitted with a welded nozzle for filling. This has a nominal diameter of approximately 100mm which does not restrict the use of either macroporous or gel type beads therefore the design ensures flexibility for future decisions depending on OEF.

6.2.21 Sub-Argument 17: Evaporation of Liquid Discharges

612. Sub-chapter 8.2 (sections 3 and 4) of the GDA PCER [Ref 47] describes the main design measures implemented in the UK EPR^{TM} to reduce the production of radioactive waste, and improve the effectiveness of the containment function, in order to reduce off-site radioactive discharges in normal operation.

613. The systems and equipment used to treat and store radioactive liquid effluent (filters, demineralisers, evaporators, degassers and tanks), help limit the radioactivity, which is eventually released into the environment when discharged into the sea.

614. The UK EPR^{TM} incorporates a number of improvements to filtration, demineralisation and evaporation techniques for treatment of radioactive liquid effluents. This argument discusses the role of evaporation in minimising discharges of radioactivity to the environment.

615. The evaporation step of the effluent treatment involves evaporating the liquid effluent and then condensing the purified distillate in order to discharge it, with the condensate constituting the treated waste. This technique therefore concentrates the activity and chemical elements present in the treated effluent into a reduced volume. The distillate has a significantly reduced concentration of radioactive and chemical products (with the exception of tritium). Evaporation is a technique mainly used on effluents containing significant contamination and is used after pre-treatment of the effluent by other techniques such as filtration and demineralisation.

616. The use of evaporation to minimise the amount of radioactivity discharged to the environment at SZC has two key aspects:

- Evaporation of primary coolant for recycling in the primary circuit [Evidence 93]; and,
- Evaporation of non-recycled liquid effluents from the primary circuit [Evidence 94].

617. The concentrated fraction left as a result of the evaporation process can either be recycled or disposed of as solid waste, thereby resulting in the reduction in the amount of activity discharged to the environment in the distillate.

618. The recycling of enriched boric acid in the primary circuit contributes to the optimisation of primary coolant chemistry and to reducing discharges of boron to the environment. Decisions on whether to use evaporation for particular non-recycled effluent streams or batches arising during operation will be taken on the basis of the chemical and radioactive composition of the effluent and the expected reduction in activity (and chemical) levels that can be achieved through the use of filtration and demineralisation. The segregation and management of effluents which enables flexibility in deciding the treatment of effluents, is discussed in Sub Argument 19.

619. The use of evaporation to concentrate activity in solid form is considered to be consistent with Principle ENDP15 on the minimisation of the releases of radioactive substances to the environment and also with the objective of the UK Radioactive Discharge Strategy [Ref 23] which discourages dilution and dispersion of radioactive waste into the environment and promotes the 'concentrate and contain' principle. The use of evaporation is considered one of the key abatement techniques and therefore contributes to these minimisation principles and considerations of BAT.

620. Review of international literature indicates that evaporation is one of four main technical processes widely used for treatment of radioactive liquid effluents, namely: evaporation, chemical precipitation/flocculation, solid-phase separation; and ion exchange. All these treatment techniques are well established and widely used. The best volume reduction effect, compared with the other techniques, is achieved by evaporation. Depending on the composition of the liquid effluents and the types of evaporators, decontamination factors range from 10-10,000, with an average range of 100-1,000. A waste volume reduction factor of 500-10,000 may be achieved.

621. Evaporation is reported to be a widely used technique in the treatment of liquid discharges arising from nuclear power generation in countries which are Contracting Parties of the Convention for the Protection of the Marine Environment of the North-East Atlantic (also known as the OSPAR convention) [Ref 108]. The report noted that there is a significant level of similarity among the systems and abatement processes and techniques applied in nuclear facilities in the Contracting Parties. This level of agreement, together with the national processes in place to implement BAT is considered to provide a strong indication that international best practice and, by extension, BAT is being applied.

a) Evidence 95: Evaporation of primary coolant for recycling in the primary circuit

622. The primary circuit is treated with:

- boric acid, because of its neutron-absorbing properties: the proposed treatment of the primary water facilitates greater recycling. The use of enriched boric acid with boron-10 significantly reduces discharges in normal circumstances. The use of enriched boric acid is discussed in Sub Argument 6 which discusses primary coolant chemistry; and,
- lithium hydroxide to reduce the acidity of the boric acid, and to regulate pH as slightly alkaline to prevent equipment corrosion.

623. Primary liquid effluent comprises liquid leaked or drained from the primary coolant water, not chemically polluted, and water from circuits containing the primary coolant, discharged when the concentration of boric acid in the primary water changes.

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

625. Evaporation is used in the overall treatment of the primary effluents after they have undergone filtration and decontamination and the degassing stage in the TEP circuit. The treatment of primary effluent during the boron

recycling process contributes to the optimisation of the chemical treatment of the primary coolant, in particular by a better elimination of the dissolved oxygen during boron recycling, by evaporation and degassing, and recombination of the hydrogen in the gaseous effluent treatment system.

626. The evaporator separates the primary coolant into a bottom concentrate containing boric acid concentrate (4%) and the distillate containing distilled water and any volatile constituents carried over in the distillation process (such as tritium). When possible, the primary effluents are reused in the primary circuit after treatment and boric acid is reused via the REA. The recycling of boron optimises the use of boron and generation of solid waste. When this is not achievable, the concentrates are sent to the TEU and the distillates are sent to the KER tanks or back to the TEP if additional treatment is required.

b) Evidence 96: Evaporation of non-recycled effluents from the primary circuit

627. The installation at SZC utilises an evaporation process for the minimisation of liquid effluents from the non-recyclable liquid waste treatment system. Evaporation results in the production of a sludge-like concentrate which contains the majority of the radioactive inventory entering the evaporation system. Evaporator concentrates also contain up to 40,000 ppm of boron and a total salinity of 300 g l^{-1}, which makes them liable to crystallise, although the SZC UK EPR^{TM} units are expected to produce sludge containing much lower levels of boron (17,000 ppm) [Ref 108]. The non-recycled effluents treated by evaporation are described below.

628. Spent liquid effluent:

- Comprises three kinds of drained liquid: residual drainage from polluted primary coolant drained or leaked from equipment after flushing; chemical effluent or drainage produced in the HN and more polluted than residual drainage; floor drainage from leaks and floor washing in different rooms;
- Is treated in the TEU installed in the waste treatment building for recycling. The BAT assessment [Ref 70] presents the assessment to demonstrate that the TEU has sufficient capacity and resilience (for example, in case of outage due to maintenance or breakdown) to cope with all the aqueous radioactive waste arising and to ensure that the use of the TEU evaporator is optimised (Argument 11); and,
- Includes the contents of the chemical drains after they have been coarse filtered. Similarly, to the primary effluents, the evaporator (distinct to that used for primary coolant in the TEP) separates the spent effluents into distillates (only weakly active and/or chemically polluted) and concentrates (contain most of the activity and soluble and particulate chemical components). The distillates are subsequently sent either to a discharge tank or back to the evaporation system for additional treatment, and the concentrates, to the TES. Process and floor drains can also sometimes be treated by evaporation in this evaporator unit.

629. Design change CFSE0384B ‘Change to the operating parameters for the evaporation station in TEU’ was reviewed for its environmental impact and determined that the design change could have the potential to impact the operation of the evaporator only if ICOI [Ref 17]. The design change updated the maximum heat exchange capacity from 310kW to 353kW and the heat exchanger flow rate on the secondary side was reduced. These two factors are dependent on the supplier being able to produce an EDS to demonstrate that the final design meets the specification set by SZC or, should it deviate, to produce a further BAT justification.

630. Evaporation is only used for those effluents where concentration and subsequent containment of activity (and chemical components) is necessary to minimise discharges to the environment and where the activity cannot be readily removed by the methods of filtration and demineralisation. Evaporation is thus normally only carried out for effluent from the chemical drains and is not routinely applied to all spent liquid effluents from the primary circuit. The selective application of evaporation thus depends on the availability of systems for the

segregation and management of effluents. The segregation and management of effluents is discussed in Sub Argument 19.

631. The evaporation techniques involved in the treatment of liquid radioactive effluents described above meet several nuclear BAT factors of the Organisation for Economic Co-operation and Development (OECD) report in particular:

i. Use of low waste technology

632. Implementing an evaporation stage in the treatment of effluent from nuclear power stations enables the minimisation of the generation of radioactive wastes from the facility by concentrating the activity into the concentrate.

ii. Reduced emissions

633. The use of evaporation techniques in the treatment of liquid effluents concentrates and contains environmentally persistent or bio-accumulative emissions and radioactive discharges by segregating the effluent into concentrate and distillate, and thus contributes to progressively reducing emissions from power stations.

6.2.22 Sub-Argument 18: Filtration of Liquid Discharges

634. Filtration of liquid discharges is used at SZC to minimise discharges of radioactivity to the environment by the removal of particulate from liquid effluent and also to optimise the efficiency of other abatement processes. Pre-filtration is used to limit the degradation of demineralisation bed material, coupled with downstream filtration to avoid the introduction of demineraliser fines as impurities in the primary coolant. Pre-filters and strainers are employed in a number of systems to protect micro-filters and minimise the generation of spent filters.

635. The abatement technologies implemented in the UK EPR^{TM} for the treatment of the effluents (in particular filtration, demineralisation and evaporation) are all in current use in the nuclear industry worldwide and have already been implemented in the UK.

636. This argument discusses the role of filtration in minimising discharges of radioactivity in particulate form to the environment, which also contributes to compliance with the RSR environmental permit condition which requires application of BAT to minimise solids, gases and non-aqueous liquids from liquid radioactive discharges.

637. The overall approach to the design and selection of filtration for the treatment of liquid effluents is based on the following key aspects:

- OEF in filtration based on a significant body of knowledge and national and international experience including:
    - EPRI recommendations;
    - IAEA documentation;
    - OEF from the French nuclear fleet and Sizewell B; and,
    - Industry standard best practice [Evidence 95].
- Optimisation of the selection of filters based on OEF and the balance between reduction of discharges and environmental impacts and increases in solid waste arisings and worker doses associated with filter management [Evidence 96].

638. The filters specified for use in the UK EPR™ primary coolant, liquid effluent treatment and spent fuel pool water treatment systems, for the removal of corrosion products associated with particulate material are selected on the basis of OEF at existing sites in France and Germany and in particular, for EPR™, those particulate filters and ancillary systems used for the 1,300MWe units.

639. The filtration selection strategy for UK EPR™ is the result of many years of accumulated experience and knowledge and can be considered as evolutionary. This information is not readily summarised as it is based on historical information and decision-making over many years of reactor operation. However, this evolutionary approach has resulted in optimised worker doses, acceptable commercial impacts, and acceptable solid waste arisings whilst achieving low radioactive discharges from all reactors [Ref 5]. Filtration is regarded as a passive treatment system (unlike, for example, evaporation) and filter units are cost effective with good operational reliability.

640. Final decisions thresholds to define the operation of the UK EPR™ with respect to primary coolant purification in the TEP and other systems (e.g. the TEU) and secondary radioactive liquid effluent treatment performance will need to be determined for SZC. At the current stage of development of SZC the detailed arrangements for the specification and application of filtration of radioactive liquid effluents have not yet been determined but the general application of filtration is shown to be BAT.

a) Evidence 97: Operational experience in filtration

641. There are a number of aspects related to filter specifications which affect the efficiency of liquid effluent abatement, thus influencing the overall effectiveness of filtration in reducing the discharges of liquid radioactive effluent to the environment. These are:

- filter location;
- filter sizing;
- filter type;
- filter cartridge porosity;
- the number of filters in series; and,
- pre-filter requirements.

642. The filters selected for the UK EPR™ will vary in specification depending on the liquid treatment system considered and will take account of the factors listed above. These choices are underpinned by guidance for the use of cartridge filters the fundamental aims of which are to provide best practice and advice to reactor operators in the fleet on the choice of filter materials, specification for filter performance and change criteria and to summarise the practical experiences of French sites [Ref 5].

643. The following recommendations were drawn from EDF guidance on the use of cartridge filters in radioactive liquid treatment systems [Ref 96]:

- fine filtration is recommended upstream of the reactor coolant pumps to avoid abrasion of hydraulic items and assure best functioning of seals;
- fine filtration is recommended upstream of demineralisers to protect them, particularly for the RCV demineralisers to retain activity at source;
- downstream of the demineralisers, up to 25 micron filtration is considered as sufficient to retain potential resin fines;
- all liquid effluent must be filtered prior to discharge – the filtration size required depends on the source of effluents;

- stainless steel structures are recommended for the filter basket and cartridges used in the RCV; and,
- polypropylene structures are recommended for the filter basket and cartridges used in the TEP, TEU, KER, and SEK.

644. An EOS report was produced to [Ref 90] justify the filter porosity for systems across the Nuclear Island and resulted in some modifications (e.g. changing of TEP filter from 1 micron to 5 micron).

645. Considering the flow rate of effluent passing through the filters, it is recommended to use baskets and cartridges made of stainless steel in the APG.

646. The use of single-use cartridge filter technology has for some time been the preferred technique for particulate removal in primary coolant and radioactive liquid effluent systems for all PWRs [Ref 85]. Different types, brands and specification of cartridge filters can be used, depending on the characteristics of the liquid to be treated. There is considerable experience in the use of cartridge filtration for PWR liquid effluent treatment and the management of spent filters. From an operational perspective these are easier to apply than alternative filtration techniques (this technology is also more reliable relative to more complex filtration systems, due to its passive simplicity) [Ref 5]. The filter types presented as part of the GDA submission were selected on the basis of OEF from the French fleet of PWRs.

647. OEF from stations has also resulted in the inclusion of an isolation valve and coupling in the TEU system in the Effluent Treatment Building; this will enable flushing of the discharge and injection pumps. The modification will enable the filters to be changed while the system continues to operate. The addition of manual isolation valves around (upstream / downstream) of filters is required. This reinforced separation (double isolation) will make the change of filters safer for workers.

648. Performance monitoring of filters is key to ensuring that system retains a high level of performance and does not compromise the design of the system in minimising the generation, accumulation or disposal of radioactive waste. The monitoring requirements for a number of in-process liquid filters including RCV, PTR and RPE are assessed in the BAT report [Ref 110].

b) Evidence 98: Optimisation of the selection of filters

649. The UK EPR^{TM} design focuses on minimisation at source and this is reflected in the choice of filtration systems for the RCV to achieve primary coolant chemistry specification, which is set at 1 micron. Experience suggests that the use of filters below 1 micron in the RCV can be problematic with respect to the generation of spent ILW filters whilst having minimal additional impact on reducing radioactive liquid discharges or worker doses [Ref 5]. Spent RCV filters arisings are anticipated to be low. Filtration in the RCV also seeks to minimise the generation of spent resin by use of pre-filtration to limit the degradation of the resin bed material and downstream filtration to avoid the introduction of fines as impurities in the primary coolant. Filtration is also used in the reactor coolant pumps to prolong the life of the seals and minimise the introduction of corrosion products from operation of the pumps. Changes to the RCV design would require significant resources, which do not appear to be necessary in light of the good performance of similarly specified systems on comparable PWR plant [Ref 5].

650. The length of the cartridge filters for two RCV coolant filters and two resin traps has been altered to 30inches. The RCV filter design has been updated to be compatible with both 28 inch and 30 inch filter cartridges. The modification is aimed at reducing the radiation exposure to operators handling concrete packages containing waste RCV reactor coolant filters, by reducing the overall length of the filters and therefore increasing the amount of shielding above the filter in the encapsulated package [Ref 111]. The modification could impact on the longevity of the filters, resulting in a very minor increase in the amount of ILW produced, however the capacity of the ILW store will be based on actual waste arisings during the initial years of operation allowing the required capacity to be predicted with more accuracy.

651. Fine filtration in the primary circuit ensures that fine particulate material is captured close to the point of generation and is not transported or further perpetuated through the abatement system. This ensures that the fine particulate fission and activated corrosion products are not discharged.

652. For other liquid effluents systems (e.g. TEP, TEU, SEK and the KER) a range of filter pore sizes are used (up to a maximum of 25 micron) and pre filters/strainers are employed to protect micro-filters and minimise the generation of spent filters. The filters used in these 'secondary liquid effluent systems' are also amenable to either volume reduction or incineration, which reduces overall solid waste disposals. Final filters for discharge are rated at 5 microns, which is consistent with Environment Agency guidance for the treatment of liquid effluents from nuclear reactors [Ref 27], [Ref 85]. The BAT assessment [Ref 90] has been completed which justified the filter porosity of systems across the nuclear island.

653. Design change CFSE0388 'Addition of pump flushing capability and isolation valves for filters in TEU' was reviewed for its environmental impact as per the design change process. This determined that the design change could have the potential to impact the operation of the TEU only if ICOI and therefore it was initially ranked E3. Further review of this modification confirmed that the design change added a pump and isolation valves to enable the filters to be changed while the system continues to operate and to provide double isolation to protect workers. This design change therefore optimises the availability of the TEU and would retrospectively be ranked E4 – as a result no further BAT assessment was required [Ref 102].

654. Filters are changed when a pressure difference (ΔP) reaches a set limit, i.e.; filter blinding, when a set dose limit has been detected or when a failure of the filter, such as a burst filter, is detected. This means that the filters are not changed at a regular frequency, but rather as and when required, and allows their full capacity to be used and not wasted, thereby minimising solid waste arisings.

655. Design change CFSE0231 'Change of the maximum allowable pressure in the TEU filters' was reviewed for its environmental impact and determined that the design change could have the potential to impact the safe operation of the TEU filters [Ref 112]. The BAT justification is dependent on feedback from the supplier to confirm that the design pressures are consistent with the filters to be supplied. For HPC, suitable justification was provided by the supplier, via their EDS [Ref 113], that their supplied filters will be compliant with the pressure requirements specified by NNB. If the supplier is the same for SZC then this justification will remain suitable, otherwise a further suitable justification will be required from the supplier.

656. An optioneering study for the SBE [Ref 114] identified that filtration was required to exclude entrained solids from any aqueous effluent discharge. A BES [Ref 114] reviewed the approach for filter porosity on the SBE and confirmed the design, including the requirement for 5 micron filters, to be appropriate. A BAT assessment [Ref 90] has also been completed for the justification of the filter porosity of filters across the Nuclear Island (NI).

6.2.23 Sub-Argument 19: Segregation and Management of Liquid Effluents

657. The segregation and management of effluents is an important contributor to minimising the amount of radioactivity discharged to the environment. There are two key elements:

- Definition of liquid effluents to achieve segregation. In designing the UK EPRTM, the categories of liquid radioactive effluent (discharges) described below were defined. This definition allows for the effective segregation and subsequent management of liquid effluent waste streams which have similar chemical and radiochemical characteristics. The segregation and management of liquid effluents is also important in the application of BAT to minimise solids, gases and non-aqueous liquid from liquid radioactive discharges [Evidence 97]:
    - Recyclable primary circuit liquid effluent [Evidence 98]. Primary aqueous liquid effluent discharges are comprised of:

        - liquid leaked or drained from the primary coolant water. This contains only chemicals added to the primary circuit: boric acid and lithium and is not otherwise contaminated by other chemicals or oils etc.; and,

        - water from circuits containing the primary coolant and discharged to downstream treatment systems in response to requirements to dilute boron through the fuel cycle (for neutron reactivity control additional to that provided by the control rods).

    - Non-Recyclable Spent Liquid effluent [Evidence 99]. This waste stream is further segregated into three types: Process Drain, Chemical Drain and Floor Drain (FD). Floor drains are themselves segregated into 3 types: Floor Drains 1 (FD1), Floor Drains 2 (FD2) and Floor Drains 3 (FD3).

    - Steam Generator Blowdown system [Evidence 100]. Blowdown water from the SGs is largely made up of feedwater. In the event of small primary to secondary leaks (or more major tube failures), this blowdown may contain low levels of tritium from the primary circuit coolant.

    - Water drained from the turbine hall [Evidence 101]. Water drained from the turbine hall comes from leakage, and from draining and emptying the secondary circuit, but excluding blowdown from the SGs.

- The design of effluent management systems, which facilitate segregation of effluents. Key systems include the RPE, the TEP and the TEU.

658. It is considered that the definition of segregated effluent streams and the design of effluent management and treatment systems for these streams for the UK EPR^{TM} are consistent with the expectations set out in the Environment Agency and ONR’s principles relating to the segregation of wastes. The effluent streams are segregated as close to the point of generation as practicable to facilitate subsequent treatment. Effluent streams are not mixed inappropriately. In the case of the UK EPR^{TM}, the segregation of recyclable primary effluent is essential to the recycling of enriched boric acid. The segregation of non-recyclable effluents from the primary circuit enables application of the most effective treatment techniques in terms of demineralisation, evaporation and filtration to ensure that as much radioactivity is removed as practicable from liquid effluent streams and converted into solid waste (the treatment techniques are discussed in Sub Arguments 15, 17 and 18) It is noted that the segregation of liquid effluent streams has no overall reduction in the discharges of tritium to the environment because the treatment techniques do not convert tritium into solid form.

659. The segregation of liquid effluents is of benefit in minimising the amount of activity discharged to the environment, in part by ensuring that where practicable effluents can be recycled and also by enabling more effective treatment of effluents to remove radioactivity.

660. Efforts have been focused at the design stage on reducing/minimising the production of effluents at source, taking account of OEF from EDF and AREVA. A number of recommendations from the EPRI have also been taken into account, such as the improvement of collection and effluent treatment systems [Ref 109].

661. These efforts, when combined with effective liquid effluent abatement techniques, have led to the amount of radioactivity disposed to the environment through the operation of the UK EPR^{TM}, to be minimised.

662. Therefore, at the design stage, the UK EPR^{TM} is expected to reduce the activity discharged in the form of liquid, excluding tritium and carbon-14, in relation to the best French 1,300 MWe units, by a minimum of 10%.

663. Upon segregation the UK EPR^{TM} design incorporates several systems, features of which enable the effective abatement and management of the segregated liquid effluent waste streams:

- Provision of systems that enable effective management/treatment of the segregated waste streams [Evidence 104]. Liquid effluent, segregated at source is treated in different systems, depending on its characteristics, to allow it either to be reused and recycled or discharged as required.
- Combining two or more liquid effluent abatement techniques [Evidence 105]. EDF has considered the advantages (in terms of minimising the disposal of radioactivity into the environment) of combining two or more liquid effluent abatement methods. It is recognised that combining two or more liquid effluent abatement techniques can have the effect of reducing the activity of liquid effluents discharged into the environment.

664. Treatment can be more effectively targeted on the relevant radionuclides if effluents are segregated and some techniques can achieve higher decontamination factors when the effluent is more concentrated. The accumulation of liquid effluents having similar characteristics will enable the UK EPR^{TM}'s liquid effluent treatment system to maximise the benefits of specific effluent management arrangements and abatement techniques. These benefits include:

- targeted radionuclide removal;
- enhanced decontamination factors as a consequence of liquid waste streams being more concentrated;
- increased plant efficiency; and,
- flexibility in effluent treatment plant availability.

665. The concentration and containment of radioactive discharges is a central objective of BAT, in order to meet the objective of the UK Radioactive Discharge Strategy [Ref 23]. To this end, the liquid chemical and radioactive effluent sorting and treatment systems are designed to minimise the activities of liquid effluents that need to be discharged from the UK EPR^{TM} and hence their subsequent impacts.

i. Use of industry recognised BAT for segregation

666. The abatement technologies implemented in the UK EPR^{TM} for the treatment of the effluents (in particular filtration, demineralisation and evaporation) are all in current use in the nuclear industry worldwide and have already been implemented in the UK. They have various efficiencies on different materials, and, in particular, some radionuclides are better removed than others (i.e. there are no current abatement techniques to reduce levels of tritium and carbon-14 in effluents). They are generally recognised as BAT independently of each other, and have been identified as relevant and reliable. In addition, in light of increasing pressure to reduce the discharge of radioactive and other materials into the environment, it is evident that substantial advantages and higher decontamination factors can be accrued by selecting a combination of two or more processes and their consecutive or simultaneous application for treatment of liquid waste. This is true for both preparing effluents for discharge and condition concentrated wastes for disposal. These processes usually involve treatment by filtration, precipitation, sorption, ion exchange, evaporation and/ or membrane separation.

667. The approach adopted by EDF/AREVA for the UK EPR^{TM} is in line with these requirements of combining several techniques to achieve higher rates of decontamination and to reduce discharges as far as possible. In addition, it is generally admitted that operators may seek to argue that the adoption and implementation of Environment Agency guidance and relevant good practice represents BAT without more detailed consideration of options and techniques. This approach is acceptable providing that the operator demonstrates that the guidance and good practice is relevant and fully applicable to the facility in question. Therefore, it is considered that, as the techniques have been approved elsewhere in the UK for similar installations, the BAT analysis carried out for the UK EPR^{TM} would lead to the same conclusion.

ii. Periodic reassessment for newly developed techniques

668. Additional BAT requirements imply that, in order to obtain the authorisations to discharge radioactive substances in the UK, the operators shall keep abreast of new abatement and treatment technologies. This is in particular to improve the transparency of the decision making process. It is believed that the techniques currently envisaged for the treatment of the liquid effluents in the UK EPR^{TM} are the best available at the current time, although it is expected that they will be periodically reassessed and potentially replaced, or added to, by more advanced techniques that may be developed in the future. This would be undertaken only if it was demonstrated that the environmental benefits gained would be proportionate to the risk involved, and the cost, time and effort of implementation. This is consistent with the BAT approach requiring ongoing optimisation and assessment of the treatment techniques in use, and consideration that BAT for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.

a) Evidence 99: Definition of liquid effluents to achieve segregation

669. The design efforts aim to optimise the sorting and processing systems. An optimal selective collection system for the different liquid effluents; in particular the three drain channels that collect effluents from the various plant areas. The effluents can then be treated separately by one or more methods such as evaporation, ion exchange and filtration. This allows a marked reduction in the activities and volumes discharged while optimising the production of solid radioactive waste from the effluent treatment systems (filters, concentrates and resins).

b) Evidence 100: Recyclable Primary circuit liquid effluent

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

671. Primary liquid effluents from these sources are collected separately to other effluent sources (by the RPE and then sent to the TEP where they are decontaminated, and the boric acid and water separated using an evaporator-degasser.

672. Hydrogen gas is released from the reactor coolant water contained in the TEP, RCV and RIS systems and will accumulate in high points of the system. These high points were initially vented via the RPE4, but it seems the hydrogen content would be too high – above the lower explosion threshold. Therefore, the venting must be routed to the RPE1 which itself is served by the TEG and will stop the build-up of hydrogen to dangerous concentrations [Ref 115]. This has the additional benefit of recycling the hydrogen through RPE1 rather than allowing it to discharge to the atmosphere.

673. Boric acid concentrates (4 % solution) and distillates from the TEP evaporator-degasser, may be reused as supplementary boric acid and water for the primary circuit coolant. Any primary effluent that cannot be recycled in this way is sent either to the on-site discharge tanks before monitoring and discharge (distillates only) or to the TEU.

674. The recycling of enriched boric acid which can be achieved as a result of the segregation of recyclable primary circuit liquid effluents is discussed in relation to primary coolant chemistry and the use of evaporation as an effluent treatment technique, as described in Sub Argument 17.

c) Evidence 101: Non-recyclable Spent Liquid effluent

675. The management of non-recyclable spent liquid effluents is described in the RSR permit head document [Ref 1]. The TEU demineralisers retain active and non-active dissolved matter. Filters retain active and non-active

particulate matter but have no abatement effect on chemical substances. The evaporator allows concentration of radioactivity and chemicals in relatively small volumes of concentrates, and results in distillates with low activity. However, the distillates still contain tritium since the evaporation process has no abatement effect on this radionuclide [Ref 116].

676. The RPE includes process drains containing polluted effluent from flushing of systems; these effluents are not recycled as they could potentially have a low boron concentration, the wrong chemical properties or too much suspended material. An additional line has been added, connecting to the RPE4 (process drain), to allow the flushing effluents to go to TEU instead of TEP. The connection line will be equipped with one or two isolation valves depending on the pressure and temperature conditions of the drained system. Effluents will be then directed towards TEU.

677. The UK EPR^{TM} design differs from current PWR designs by improvement to the selective collection of floor and chemical drains (3 categories of floor drains). Only the most active "FD1" floor drains effluents (potentially contaminated) are expected to routinely require treatment using the radioactive waste evaporator. Effluents from the "FD2" floor drains (potentially not contaminated) and "FD3" floor drains (products outside of the controlled area) are expected to routinely require only filtration prior to discharge. Mixing and cross contamination of active FDs with low activity FDs is thus avoided. The UK EPR^{TM}'s design therefore incorporates design features that greatly facilitate segregation and selective treatments that, at currently operating plants, are more difficult to implement (for example, they require multiple transfers and redirection of effluents through various sumps in the plant to effect selective treatments).

d) Evidence 102: Management of laboratory sample effluents

678. Sampling of active effluents at SZC is carried out for the purposes of in-process and discharge monitoring (Claim 5). The SZC in-house laboratory will carry out analysis of samples and ensure spent samples, and any chemicals used, are segregated and disposed of to the most appropriate discharge route, in accordance with waste hierarchy principles.

679. A BAT assessment [Ref 69] details an update to the design of the HN Hot Laboratory drains to the RPE. A new sink will be added to the laboratory for disposal of active samples analysed by the addition of chemicals; the correct disposal route is to RPE5, the original UK EPR^{TM} design routed all the sinks to the RPE7. The new sink will ensure correct segregation of the chemical samples into the RPE5 chemical system for appropriate treatment and disposal.

e) Evidence 103: Effluent management in the Liquid Waste Processing System

680. The TEU has a highly flexible arrangement that will enable bespoke treatments for particular effluent streams depending on the characteristics of the effluent. The system receives effluents from process drains, chemical drains and floor drains. Design changes made to the UK EPR^{TM} for this system include:

- Design Change CFSE0566 ‘Sensitivity to the electrical power cuts of the KRT channels’ was reviewed for its environmental impact. This determined that the design change could have the potential to impact the performance of KEPE, which if it became unavailable, could reduce the ability to prevent high activity effluents from being sent to the discharge system. Stage 2 EOS based on the HPC RC1.2 design to review the operability and availability of the equipment concluded that the electrical and back up requirements, as stated in the contract specification, complied with the relevant standards and further evidence will be provided by the supplier to demonstrate that the specification is met [Ref 119]. This design change presents no change to the design basis of the TEU or in the ability to monitor the TEU distillates.
- Design change CFSE0419UK ‘Optimisation of control of Liquid Waste Treatment System distillates before release to effluent’ was reviewed for its environmental impact. This determined that the design change could have the potential to impact the monitoring of evaporator performance and

the representativeness of such monitoring, the segregation of liquid wastes and ultimately impact the quality of effluent sent to the KER discharge system. An Environmental Optimisation Study [Ref 118] was completed to assess a number of options to determine the BAT approach for monitoring effluent following treatment by the evaporator and prior to discharge to the KER. The addition of a flow proportional sampler to the distillates discharge line along with the use of the radiation monitor to detect when effluent was suitable for discharge to KER and to provide a representative sample for full analysis was concluded as the BAT option.

- Design Change CFSE0441 titled ‘Upgrade of classification and pressure rating of part of pipework in the TEU’ was reviewed for its environmental impact. This determined that the design change could have the potential to impact the pressure or sizing of the system and could ultimately impact the performance or operation of KEPE. A sizing report [Ref 70] demonstrated that the design of the TEU meets the original design intent but that a System Level BAT review will be required to demonstrate that the overall detailed design, including the sizing and pressure requirements of the system are BAT.
- Design Change CANP0025 ‘Routing flushing effluent RPE outside the Reactor Building’ was reviewed for its environmental impact. This determined that the design change could have the potential to impact the volume of effluent routed to the TEU. This design change provided an additional line to transfer effluent generated by the flushing of the TEP in to the TEU process drain head tank via the RPE. This enables the direction of non-recyclable effluent directly to the TEU instead of the TEP via RPE. A subsequent sizing assessment [Ref 70] was produced to demonstrate that the TEU is sufficiently sized to cope with the volumes of effluent expected from all RPE routes. A System Level BAT review will be required to demonstrate that the overall detailed design, including the sizing and pressure requirements of the system are BAT, however, no specific BAT assessment was required [Ref 102].
- Design Change CSFL0427 ‘Modifications to pipework applying to systems including REN, RPE and TEU’ was reviewed for its environmental impact and determined that the design change could have the potential to impact the ability to take representative samples from the REN, a BAT assessment of the sampling process was considered not necessary as the sampling will be reviewed in the EOS reports [Ref 102]. In addition, it was noted that TEU performance would only be impacted by the design change to pipework if ICOI and was therefore not considered significant risk.
- Design Change CFSE0529 ‘Diaphragms added on mixing and filtering lines of TEU storage tanks’ was reviewed for its environmental impact and determined that the design change could have the potential to impact the representativeness of the TEU monitoring and efficiency of filtration. The original design issue was that a study of the flowrate of the system identified that in some configuration the pressure within the system was above the require operating parameters. The BAT review, captured with the HPC IC9 report [Ref 112], identified a number of options as follows:
    - Change the pump speed to ensure that the operating pressure is not exceeded.
    - Change the pump speed and the pipework diameter to ensure that the operating pressure is not exceeded.
    - Include orifice plates to mitigate the impact of pump speed on operating pressure.
    - Include control valves to mitigate the impact of pump speed on operating pressure.

681. The BAT justification considered the feasibility of each option as well as the potential impact on system design and project impacts. The option to add valves was considered not to be BAT due to the operational burden and system impact of adding new valves and additional I&C requirements. The BAT justification concluded that given the design state of the system at the time, no single option was identified over another as being BAT. The final decision is dependent on the system sizing to ensure the operational pressure requirements can be met. The BAT justification demonstrates this design change does not impact the TEU design.

f) Evidence 104: Effluent management in the Steam Generator Blowdown System

682. This effluent source is normally directed to the SG blowdown treatment system where it is filtered and demineralised, then recycled to the main turbine condenser. Exceptionally, when recycling is not possible, the blowdown is sent to the KER tanks [discharge tanks] before monitoring and discharge.

683. During each shutdown, the APG will be drained for maintenance. Each of the 4 SGs are drained, one at a time, into the KER liquid waste system. Draining under gravity takes too long to be compatible with the short shutdown period. A portable pump has been included in the design for operation during outages [Ref 121].

684. A transfer line has been added between the SGs. In the event of a SG Tube Rupture (SGTR), liquor can be transferred from one SG to another prior to both SGs being rinsed to the RPE. This limits direct gaseous releases but leads to more radioactive liquid effluents having to be stored and treated via the TEU. Overall this represents good effluent management post-SGTR [Ref 101].

g) Evidence 105: Water drained from the turbine hall

685. Drainage water from the turbine hall is classified into two categories; effluent with potential radioactivity which are sent to the SEK tanks for treatment and hydrocarbonated effluents (i.e. effluents that for example contain oil). The latter are sent via an oil separator to remove hydrocarbons, before being sent to the SEK tanks.

h) Evidence 106: Provision of systems that enable effective management/treatment of the segregated waste streams

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

687. The RPE plays a key role in the segregation of effluent at source and direction to appropriate treatment routes. The operational functions of the system are as follows:

- Selective collection:
  - of the different categories of liquid and gaseous effluent defined according to the appropriate treatment method, and produced by the primary system, the reactor auxiliary systems and the nuclear auxiliary systems of the nuclear island; and,
  - of the different categories of liquid effluent, defined according to the appropriate treatment method, and produced by the decontamination facilities (e.g. showers, floor washing).
- Selection of primary system effluent (hydrogenated or aerated) to recycle the boron therein as far as possible.
- Channel the liquid effluent collected to the storage tanks dedicated to each effluent category, before treatment in the effluent treatment system.
- Channel the gaseous effluent collected towards the appropriate treatment.

- Purging of the primary system before it is opened for de-fuelling for example, and venting before and during filling after refitting of the vessel head.
- Collection of effluent discharged by the safety valves of systems containing primary coolant and channelling to the primary coolant tanks.

688. An additional sump has been added in the annular space in the reactor building in order to ensure the separation of the annular space ventilation system and the internal structure ventilation system [Ref 68]. The sump in the internal structure evacuates effluent to the TEU, the sump in the annular space evacuates effluent to the RPE. The provision of an additional sump prevents contaminated effluent from the internal structure polluting the non-contaminated effluent in the annular space.

689. Liquid effluent evacuated from the Spent Fuel Cask Transfer Facility (SFCTF) is managed to ensure that boric acid can be recycled, and that liquid effluent can be segregated and evacuated to different RPE drains according to expected contamination levels. The segregation reduces the amount of radioactive waste produced [Ref 122].

690. In order to have an optimised management of drains and wastes from the SFCTF and to support boron recycling, the following liquid effluent evacuation routes in normal operating conditions are required:

- Evacuation to RPE1 (primary effluents):
    - Draining of the penetration (before and after filling with SED water).
    - Draining of the case.
- Evacuation to RPE4 (process drains):
    - Cleaning and flushing of the lines and of the valve tools.
- Evacuation to RPE6 (floor drains 1):
    - Draining of the cooling skirt (no chemical pollution considered) in the fuel building and in the lifting station.
    - Draining of several capacities (drip recovery of the condensation due to the drying of the cask, downstream of the vacuum pumps, low level of the transfer machine, header of the drip-off).

691. Two additional pneumatic valves are required to connect to the SFCTF to the RPE drains and the retention pit will be used only as a back-up since there is no means to pump or drain it and a mobile pump will be used as necessary. A water level measurement or a volume flow meter will be used to determine the volume of liquid effluent in the retention pit.

692. The RPE also collects resins routed from the RES. These resins are discharged into an intermediate sump, which also collects output from the floor drains. This sump can be completely emptied to the general chemical drain sump. This is an improvement on the original design configuration, where, the slope between the resin tank and original collection sump would have been inadequate to ensure transfer of the resin under gravity. The final design will be justified by the supplier EDS [Ref 17]. Also, operating experience shows that contamination by Ag110m would have been a concern in the original configuration.

693. Treatment methods employ techniques to ensure that as much of the effluent as possible can be reclaimed and reused and, where this is not possible, discharges of dissolved and radioactive materials to the environment and their impacts are ALARP.

694. Primary liquid effluent is treated in the TEP. The spent liquid effluent is treated in the TEU installed in the waste treatment building for recycling. The TEU shared by the UK EPR^{TM} units is provided for storage, treatment and monitoring of the non-reusable spent liquid effluent collected by the bleed and vent system (RPE), before transfer to the discharge system (KER or exceptionally the TER). The system also treats effluent from the TER, KER and SEK, if retreatment is needed. The TEU performs the following functions:

- in conjunction with the TEN, analysis of the content of each head storage tank and direction to the appropriate treatment facility;
- treatment of the spent effluent so as to achieve an acceptable quality for discharge to the environment;
- discharge of the treated effluent after monitoring; and,
- transfer of waste produced by treatment to the TES (concentrates, ion-exchanging resins, used filters, etc.).

695. The design of the TEU allows flexibility of operation. It enables routing of liquid effluent from each head storage tank to the appropriate treatment line as required. The operator may select a combination of treatment according to the chemical and radiochemical characteristics of liquid effluent arisings and/or adopt a strategy aiming at balancing the production of solid waste with the quality of liquid discharges. Although ‘preferred’ routes are anticipated for the various types of spent liquid effluent [Sub Argument 19], the inherent flexibility of the TEU allows routing of effluent to alternative treatment lines, i.e.:

- The process drain may be filtered and evaporated instead of demineralised;
- the chemical drain may be filtered instead of evaporated; and,
- floor drains may be demineralised and evaporated instead of filtered.

696. Therefore, up to three types of spent liquid effluents can be treated simultaneously in the TEU if they are treated on their respective ‘preferred’ lines. Should one type of effluent require routing to an alternative line, two types of effluent may be treated simultaneously (i.e. one on its normal line and the other on its alternative line).

697. The drainage water from the Turbine Hall is either processed in the system that processes blowdown water from the steam generators (APG) or sent to the on-site discharge tanks for drainage water (SEK tanks) for discharge.

698. Design change CIG5004 [Ref 123] relates to the introduction of an additional drainage system in the HK. The addition of fixed floor drains in HK allows drainage of the Protection and Distribution of Nuclear Island Fire Fighting System (JPI) to RPE without use of a flexible hose. This limited the risks associated with the use of flexible hoses [Ref 123].

699. The sorting and processing systems described above meet several nuclear BAT factors of the OECD report [Ref 103] in particular:

- Use of low-waste technology: The optimisation of the sorting and processing systems (in particular the selective collection of floor and chemical drains) enables the minimisation of the generation of radioactive wastes from the nuclear facility.
- Efficient use of resources: The implementation of the selective collection system enables a marked reduction in the activities and volumes discharged, both in terms of liquid effluents and volume of solid waste produced.
- Reduced emissions: The segregation of the drains enables the operator to concentrate and contain radioactive and chemical discharges, or other environmentally persistent or bio-accumulative emissions.

700. Correct and accurate waste characterisation coupled with monitoring and sentencing will facilitate optimal application of the waste hierarchy. In order to address waste at the highest practicable level of the waste hierarchy, improved waste characterisation is required so that further downstream segregation and categorisation to avoid or minimise waste can be applied.

i) Evidence 107: Combining Two or More Liquid Effluent Abatement Techniques

701. The UK EPR^{TM} will have a liquid effluent treatment system that will employ a number of techniques (the techniques set out elsewhere under argument 12) that individually, or in combination will be capable of providing an optimised treatment process for the full range of potential aqueous effluents that may be produced across the plant. The precise technique or combination of techniques, to be used for a given effluent stream will be dependent on the physical, chemical and radiological nature of that particular effluent.

702. The approach adopted by EDF/AREVA for the UK EPR^{TM} is capable of combining several techniques to potentially achieve higher rates of decontamination and to reduce discharges as far as reasonably practicable.

703. The application of materials with combined properties as well as the application of combined processes themselves allows effective treatment of wastes of a complex chemical nature, which are otherwise difficult to treat by traditional or conventional processes and techniques.

6.2.24 Sub-Argument 20: Decay Storage of Liquid Effluent Prior to Discharge

704. Decay storage takes advantage of the radioactive decay of short-lived radionuclides by storing effluents for a period of time of sufficient length to reduce the total amount of radioactivity discharged into the environment. The most significant short-lived isotopes present in liquid effluents from the UK EPR^{TM} include iodine-131 and cobalt-58. It is important to note that both of these isotopes are removed from liquid effluent as a result of demineralisation, filtration (for cobalt-58) and decay in the effluent treatment systems prior to transfer to the KER tanks. Only residual amounts are thus expected to be present in the effluent in the final discharge tanks prior to any storage period preceding discharge.

705. The SZC design includes large discharge tanks in the KER and SEK which will hold liquid wastes after abatement but prior to discharge to the sea. The SZC liquid effluent discharge system tanks include the capability to transfer effluent to the discharge tanks located in the TER, in the event that discharges to the environment from the KER and SEK is not possible. These site discharge tanks are designed to provide the means to sample and monitor the effluent to ensure it meets the necessary limits and parameters for discharge to the environment; the design includes failsafe links that ensure that the discharge may be stopped if the proportional flow sampler, and flow meter used for discharge accounting/reporting, are unavailable to prevent unmonitored discharges from being discharged to the environment [Ref 124]. The tanks have a substantial storage capacity with sufficient capacity to cover all reactor operating scenarios and buffer capacity in the event of faults [Evidence 106]. The tanks are not specifically designed for decay storage, though subject to operational constraints, some benefit can be taken in terms of the decay of short-lived isotopes, from the period of storage of the treated effluent in the tanks prior to discharge.

706. Iodine-131 has a half-life of 8 days. Within a period of 56 days (7 half-lives) this isotope is reduced to a very low level so storage for this period will reduce discharges to very low levels. The total reduction in activity will depend on the capacity of the discharge tanks and the duration of storage in the tanks. The longer the storage period the greater the decay of any remaining short-lived isotopes in the effluent. The capacity of the tanks, together with activity undertaken on the site that's generates liquid effluents, management and operating procedures, will determine how often the tanks are discharged.

707. The OECD [Ref 103] states that the decay storage of liquid has three main strengths:

- Use of low-waste technology (no secondary wastes).
- Resource efficiency (does not require any further management or physical resources).

- Reduction of emissions (reduces radioactivity released to the environment) [Evidence 106].

708. Utilisation of the hold-up tanks which are already part of the SZC design for decay storage is expected to be of some, but limited benefit in reducing the overall amount of radioactivity released to the marine environment.

709. The tank sizes are based on the need to have sufficient storage space to deal with contingencies. This means there is additional reserve space. Therefore, whilst the tanks are not specifically operated as dedicated delay and decay systems, there is some benefit afforded from of the size of the tanks and the time is takes to fill and discharge. Nevertheless, the controls and abatement techniques in place mean that decay storage of liquid radioactive effluents is an advantageous rather than necessary step in the management of radioactive liquid effluents.

a) Evidence 108: Evidence for the use of discharge tanks to allow radioactive decay

710. Environment Agency Guidance [Ref 126] states that for “nuclides with short half-lives that decay to stable (or less hazardous) nuclides, storage prior to discharge represents an option for abatement”. This process of decay reduces the activity in the liquid and therefore minimises the amount of radioactivity discharged to the environment. “For radioactive decay to reduce the inventory of any nuclide to 10 % of its initial value requires a storage period of between three and four half-lives. This delay option is therefore viable only for shorter lived nuclides” [Ref 126]. The following evidence comes from the OECD [Ref 103] and is used in the GDA PCER Chapter 8 [Ref 47].

711. The systems for storing and discharging the liquid radioactive effluents are on the one hand designed to check and quantify the activity of the effluent before discharging it, and on the other hand to minimise the impact of liquid radioactive effluent on the environment by achieving optimal dilution and dispersion.

712. These planned discharge tanks will offer very substantial hold-up capacity with sufficient capacity to cover all reactor operating scenarios. They will also offer buffer capacity in the event of faults.

713. The operators can also optimise the use of the storage capacities offered by the various discharge tanks before discharge to sea. In particular, they will offer the option for extended hold-up of discharges allowing increased radioactive decay of short lived nuclides such as iodine 131 and cobalt-58 over and above that possible in current lower capacity discharge systems.

714. The storage systems described above meet several nuclear BAT factors of the OECD report [Ref 103] in particular:

- Use of low-waste technology: The storage systems implemented on the UK EPR^{TM} will minimise the discharge of radioactive wastes from the nuclear facility by allowing increased radioactive decay of short lived radionuclides in discharge tanks.
- Efficient use of resources: The storage and discharge systems will enable:
    - the minimisation of generation of radioactive waste which in turn will improve the eco-efficiency of the nuclear facility (e.g. emissions per GW); and,
    - ptimal dilution and dispersion of the liquid effluents, thus optimising both radioactive and non-radioactive impacts to reduce the environmental footprint of the facility.

715. Reduced emissions: The use of discharge tanks to allow for increased radioactive decay of short lived nuclides contributes to:

- contain radioactive and chemical discharges by same place; and,
- progressively reducing discharges and emissions.

716. Leakage from circuits and components are collected in the RPE and treated according to their origin. They are sent, with liquid discharges that cannot be recycled, to the waste treatment systems, where there are stored in tanks for activity decay, before monitored release into the sea.

6.2.25 Sub-Argument 21: Control of Fuel Pool Water Conditions

717. It is expected that only a small minority of fuel elements will show any indication of fuel cladding integrity failure before being transferred for storage in the spent fuel pool. By controlling conditions in the pool water, it is expected that the fuel assembly cladding integrity will be maintained throughout the storage period. This will ensure that the radioactivity remains inside the fuel, rather than escaping and being discharged or disposed of to the environment in solid, liquid or gaseous wastes. The key parameters controlled will be pool water temperature and chemistry.

a) Evidence 109: Control of Pool Water Temperature and Chemistry

718. The frequency of cladding failures increases when the fuel and its cladding are subjected to high temperatures and when the chemistry of the medium surrounding the fuel is such as to promote cladding corrosion.

719. The primary consideration in maintaining fuel integrity in the long term is maintaining a storage environment conducive to the preservation of fuel containment through the provision of effective heat removal and conditioning of the storage medium.

720. Wet interim storage has been employed over many years as buffer storage for reprocessing plant and for long-term interim storage. In such facilities, spent fuel integrity is maintained over the long term by:

- maintaining pool water temperatures at levels which promote spent fuel heat dissipation and prevent, or at least reduce the rate of degradation mechanisms; and
- maintaining the water chemistry characteristics to prevent or reduce cladding degradation mechanisms through control of phenomena such as:
    - H_2 ‘pick-up’;
    - H_2 redistribution;
    - Water induced corrosion; and,
    - Mechanical load.

721. The key systems in the design of wet storage facilities in relation to maintaining fuel integrity are then:

- storage pool water cooling system; and,
- storage pool water purification system.

722. In relation to heat removal, temperature limits will be set for systems which could either be the subject of temperature enhanced degradation mechanisms or that play a role in the heat removal process. These will include:

- the fuel cladding itself;
- the pool water; and,
- the pool structure.

723. These will be based on knowledge accumulated regarding the properties and behaviour of relevant materials garnered from international experience. These limits will then determine the heat removal capacity required of the PTR and will be fed into its design.

724. These limits, since they have safety significance, will be periodically reviewed and revised as necessary based on operational experience and inspection and monitoring feedback, particularly that relating to cladding condition. This will be necessary for the periodic safety reviews required under the Nuclear Site Licence to ensure the continuing validity of the safety case.

725. As mentioned above, the assemblies are stored at low temperature (typically below 45°C), which limits or even prevents the occurrence of temperature related phenomena. As such, no changes in the spent fuel pins' characteristics are expected over the interim storage period, since the chemistry of the pool water will be carefully managed, and optimum operating conditions maintained. This has been confirmed as being manageable by over 30 years of international OEF.

726. Embrittlement of the fuel cladding may occur due to irradiation and oxidation-hydridation of the materials. However, it has been shown that the corrosion of the zirconium alloys in water at low temperature is minor. Operating experience has provided evidence that galvanic corrosion can be discounted.

727. In addition, mechanical tests have been carried out on Zircaloy 4 skeleton components from highly irradiated assemblies. The results of these studies have indicated that safe handling of the assemblies will be possible under normal operating conditions at the end of the interim storage period. However, embrittlement of the Zircaloy 4 skeleton may reduce the assemblies' impact resistance under accident conditions. The handling procedures will take this into account.

728. The risks from handling accidents are minimised as the assemblies are placed in storage racks in the conditioning cell. The use of the racks minimises the number of handling activities required and protects the assemblies from potential impacts that may damage them during handling activities between the conditioning cell and the storage pool [Ref 32].

6.2.26 Claim 2, Argument 13: Minimisation by the Management and Abatement of Radioactive Gaseous Effluents

729. It is important to recognise that the production of radioactive gas is primarily minimised at source. However, where radioactive gaseous effluent is unavoidably generated, the UK EPR^{TM} design employs a range of gaseous abatement techniques which ensure that radioactivity within the gaseous waste stream is minimised prior to discharge to the environment. The gaseous waste discharge system consists of an assortment of techniques, which when taken into consideration as a whole, demonstrate the use of best practice.

730. Gaseous radioactive effluent contains a number of radioactively contaminated particulates and gaseous species, including tritium, carbon-14, iodines, noble gases and other fission or activation products. The gaseous discharge system attempts to abate these radioactive particulates and gases by using the following techniques:

- Filtration – Pre-filters and HEPA filters abate the small volume of fission and activation products associated with particulate within the gaseous discharge system. Iodine filters are implemented during both normal operation and accident conditions in order to abate Iodine if a pre-determined level of activity is exceeded (Sub Argument 24).
- Decay Storage – Noble gases such as krypton and xenon, which have a high activity level and short half-life, are abated using decay storage. Although decay storage does not exclude radioisotopes from the eventual discharge, it is especially useful in reducing the release of activity in cases where there is no other viable treatment option.

731. It is important to note that whilst noble gases, isotopes of iodine, and other fission or activation products are abated within the gaseous discharge system, both tritium and carbon-14 are not.

732. It is not practicable to minimise tritium within the gaseous discharge system by partitioning it to a solid waste stream via abatement. Therefore, tritium present in the gaseous waste stream is partitioned into the liquid waste stream for disposal as far as is reasonable practicable. As a result, there is a significant reduction in tritium released from the gaseous discharge system. Information on partitioning can be found in Argument 20.

733. Due to the lower radiological impacts of carbon-14 per unit discharge for gaseous discharges compared to liquid discharges, the majority of carbon-14 discharged to the environment is in gaseous form – this is also discussed further under Argument 20. Assessment of alternative techniques for the abatement of tritium and carbon-14 are covered by Argument 14.

734. In conclusion, the gaseous discharge system for SZC has implemented a number of abatement techniques which demonstrate the use of best practice when operated in unison. Where gaseous abatement techniques have not been implemented for tritium and carbon 14 gases, partitioning and a number of other techniques have been taken into consideration. Where the cost of implementing such techniques is grossly disproportionate to the benefits gained, these techniques have not been implemented within the UK EPR^{TM} design. Therefore, gaseous abatement techniques incorporated within the UK EPR^{TM} design ensure the minimisation of the amount of radioactivity discharged to the environment where practicable.

6.2.27 Sub-Argument 22: Decay Storage of Gases Prior to Discharge

735. Decay storage takes advantage of a natural property of radioactive substances where the radioactivity progressively reduces over time. Retaining radioactive gases prior to discharge to allow decay to take place will reduce the activity of the gaseous wastes discharged to atmosphere. This is particularly relevant for those gases that are difficult to abate because they are not chemically active, such as the fission product noble gases krypton and xenon. Isotopes of iodine, another fission product, are also released in gaseous discharges. Decay storage is applicable to isotopes of short half-life and which would be discharged to the atmosphere with relatively large activity associated with the gaseous release, in the absence of decay storage.

736. Taking advantage of decay storage of gaseous wastes in the SZC design is important in the overall reduction in radioactive releases to the environment.

737. Charcoal delay beds are a known and widely used technology and are in operation at other nuclear power stations, including Sizewell B. The charcoal in the delay beds works by adsorbing the gas as it passes through the beds. The time the gas spends in the charcoal beds is based on the rate at which the gas adsorbs into the charcoal, which depends on the van de Waals forces associated with the gas. The design of the system is such that for isotopes of xenon the delay period is 40 days and for isotopes of krypton it is 40 hours. This length of time is based on the German safety standard referred to as the Nuclear Safety Standards Commission (KTA) [Ref 127]. This is considered an optimal time to store noble gases. For example, a 50 % increase in decay time would result in a 0.02 % saving of krypton-88 and 0.47 % saving in Xenon-133 discharged [Evidence 109]. It is therefore considered that the proposed decay periods are optimised.

738. The design of the TEG is based on the system used in the KONVOI reactors. To ensure compliance with the German safety standards the systems has additional capacity meaning that the retention of noble gases is greater than the KTA standard. Discharge of isotopes of iodine, remaining in the gaseous phase after partitioning are also minimised using charcoal delay beds. Isotopes of iodine are delayed at a similar rate to xenon-40 days. The only noble gas isotope which does not significantly decay in this time period is krypton 85, which has a half-life of 10.72 years, and therefore decay storage is not reasonably practicable.

739. The charcoal delay beds, and the way in which they are operated, will be designed to take account of changes in reactor operation which may result in an increase in gases through the system, for instance, during start-up and shutdown, further detail is provided in [Evidence 109].

740. Decay storage is a well-used and understood technology which has the advantage over other technologies in that it does not produce significant additional secondary wastes. The charcoal beds are expected to last for the operating lifetime of SZC. Secondary waste arisings associated with decay storage are thus considered to be minimised. However, it is important that the beds are designed and operated at the optimum level of efficiency to enable the greatest possible reduction in activity. It is also important that the selection of the charcoal to be used in the beds is made at a relatively early stage, in comparison with the selection of other abatement consumables.

741. The storage of gaseous wastes to allow decay of short-lived radionuclides is considered to be an important element of BAT with respect to the minimisation of radioactivity discharged to the environment.

a) Evidence 110: Decay of short lived gases including krypton and xenon using charcoal delay beds

742. "For nuclides with short half-lives that decay to stable (or less hazardous) nuclides, storage prior to discharge represents an option for abatement" [Ref 126]. This process of decay reduces the activity in the gas and therefore minimises the amount of radioactivity discharged to the environment. "For radioactive decay to reduce the inventory of any nuclide to 10 % of its initial value requires a storage period of between three and four half-lives. This delay option is therefore viable only for shorter lived nuclides" [Ref 126].

743. Treatment of gaseous effluents from the various tanks and systems serving the primary circuit in the UK EPR^{TM} is carried out in the TEG. This is different to that used on French PWRs but uses best current methods developed for the German KONVOI design.

744. Decay of radioactivity associated with noble gases is already undertaken as part of the operation of PWRs such as Sizewell B. "The gases from the RCV are passed through a large bed of granulated activated carbon. This 'holds up' the gases for a period of up to several weeks and allows the short lived noble gases to decay" [Ref 127].

745. Included in the basic functional requirements of the TEG of the UK EPR^{TM} are processes which:

- sufficiently delay the radioactive gases (xenon, krypton) before discharging them to the DWN;
- increases the pressure in the delay beds to increase the storage capacity of the delay line; and,
- use activated charcoal to delay the noble gases and reduce the required volume of the delay line.

746. The German Regulation, the KTA 3605 Safety Standard [Ref 127], specifies the hold-up times of isotopes of krypton and xenon. "The hold-up time of a gaseous component is the arithmetic mean weighted over the distribution frequency of the dwell time of this gas component in the off-gas treatment system. It depends on the chemical and physical properties of the gas component under review" [Ref 127].

747. The standard specifies hold-up times for krypton and xenon of 40 hours and 40 days respectively. This applies to off-gas sources including coolant degassing, coolant treatment, coolant storage tanks, volume control surge tanks, plant drainage, reactor pressure vessel flushing and pressuriser relief tanks. Off-gas treatment units include activated charcoal absorbers and buffer tanks with iodine and aerosol filters [Ref 127].

748. The line of three activated carbon delay beds retain residual noble gases that have not already decayed within the recirculating part of the system. They thus provide a further period for the decay of these gases prior to discharge, viz. xenon is kept for 40 days and krypton for 40 hours. These timescales are calculated based on the half-lives and the dynamic absorption coefficients of the nuclides, the flowrate of the carrier gas and the mass of charcoal; the delay time is between eight and ten times the half-lives of the considered nuclides, as the benefit of further delay is not significant. Parameters such as temperature, pressure, moisture, etc influence the process of dynamic adsorption and are taken into account in the design of the delay beds and their operating conditions. Note these beds are not specifically used for decay of iodine isotopes, as these are purposefully retained mainly in the liquid phases [Evidence 145]. However, considering the mass of iodine molecules, the delay beds may have the same decay effect as that of xenon (40 days). The KTA standard [Ref 127] states that "When achieving the retention times for xenon and krypton specified, the associated design of the adsorber bed is bound to result in an almost complete retention of iodine."

749. When the reactor is at power, in normal operation, a small proportion of the purge gas in the system is bled off and discharged via the three activated carbon delay beds. All purged gas passes through a heat-exchanger cooled gas drier, and separate gas cooler, to remove moisture from the gas, to ensure moisture is removed from any gas discharged via the delay beds.

750. During start-up and shutdown, the operating pressure of the delay beds is increased ('surge gas' mode) to ensure decontamination of the excess gas. This maximises the storage capacity of the beds. During surge gas mode a dessicant based gel drier is put into service to ensure moisture is removed from the gas, preserving the efficiency of the charcoal in the delay beds, which is sensitive to moisture.

751. The implementation of nitrogen distribution system (SGN) nitrogen flushing through the TEG desiccator to the DWN allows the regeneration of the desiccator. The regeneration of the desiccator will reduce the environmental impact of the delay gasses. During regeneration the purging gas upstream of the Gel Dryer is heated with trace heating which accelerates the regeneration process [Ref 128]

752. In order to ensure the performance of this drier, it is also possible to regenerate dessicant using nitrogen [Ref 129]. Redundancy has been incorporated into humidity monitoring equipment to ensure that it is available at all times. In addition to the delay beds, the containment inter-space ventilation system will delay the time it takes to discharge by recovering off-gas and returning it to the system for use [Evidence 110] The gas which includes shorter-lived radioactive gases (mainly inert gases) is retained within the TEGfor return to the various ullages and headspaces in the tanks from which it originated, maximising recirculation and minimising discharges. This feature is an improvement to the UK EPR™ design.

753. A BAT assessment was produced to demonstrate that the specification for the charcoal for the TEG delay beds represents BAT [Ref 130]. The bare minimum requirement for any charcoal selected for use in the delay beds is to fulfil the delay period of 40 days for isotopes of Xenon and 40 hours for isotopes of krypton. The study considered OEF on charcoal used at the German KONVOI plants (Carbo Tech GmbH VRG 3), and that from qualification tests of selected charcoals for FA3 carried out by two Italian laboratories Dipartimento di Ingegneria Civile e Industriale (DIMNP) at the University of Pisa, and Consorzio Polo Tecnologico Magona (CP™) at Cecina. In order to select the charcoals to be tested eight charcoal suppliers were contacted. Of these eight, three were able to supply charcoal of the required specifications.

754. The specifications [Ref 61] were based on the following requirements:

- Specific area of greater than 900m^2/g, to ensure good adsorption.
- Good grain shape to enable good filling of the delay bed and minimise dust production.
- Diameter range between 1.0 to 3.5mm, to ensure the grain size distribution and settled density will allow the overall pressure drop to be respected.
- Bulk density range from 490 to 550kg/m^3, based on knowledge of technology.
- Hardness greater than 95% (ASTM 3802), to minimise dust production and robustness of material.

755. No environmental issues specific to the risk and safety phrases were highlighted with the use of the different options of charcoal, so the above specification and the 40 hours/40 days' requirement were the primary means of assessment as well as whether OEF is available for their use at existing PWR's. The source of the charcoal was also factored in, as some of the charcoals are considered to come from sustainable sources, some from non-sustainable sources, and others a mixture.

756. The report recommended either Carbo Tech GmbH VRG 3 (used at KONVOI plants) or Norit R2030 CO2 (to be used at FA3) as the option that recommends BAT. As yet Norit R2030 CO2 charcoal is not qualified for use in FA3, and it may be that feedback from the FA3 FAT could be useful in the final choice of charcoal. This has been captured as forward action on the open point register.

b) Evidence 111: Control of rate of flow through the Gaseous Waste Processing System

757. Significant flow rates through the TEG are planned, occurring mainly during start-up and shutdowns.

758. Higher discharge rates occur only during reactor start-up and shutdown when there is a relatively larger movement of water between interconnected systems and when there is increased nitrogen purging of vessels

and the space under the reactor pressure vessel head. At this time the operating pressure of the delay beds is increased thus maximising their capacity.

759. The charcoal delay beds, and the way in which they are operated, will be designed to take account of changes in reactor operation which may result in an increase in gases through the system, for instance, during start-up and shutdown. The design of the TEG enables control of rate of flow of gases to take account of such planned increases. During start-up and shutdown, the operating pressure of the delay beds will be increased to increase capacity of the delay beds, which is known as 'surge gas' mode. This maximises the storage capacity of the beds.

760. The pressure increase in the delay unit of the will impair the dew point reduction by expansion, however it is necessary to ensure moisture levels are low in order to optimise the retention efficacy of retention of decay beds. To remove moisture from the gas prior to the delay beds, the gas passes via the silica gel drier. The gel drier is located upstream of the delay beds, and switched into service in surge gas mode to dry the gas and ensure maximum efficiency of the delay beds [Ref 128].

761. The operating conditions of the TEG have been modified to implement a fully automated I&C system in order to avoid the plant operating for long periods of high flow rate [Ref 131]. This was included after it was found that long periods of high flow could prevent the required 40d/40h decay of Xenon and Krypton respectively. Four options were considered during MODEM 2013-35 to address this issue [Ref 132]. The implementation of a fully automated I&C system was considered the best option. The modification to the I&C ensures that changes in flowrate during surge gas mode are alarmed to indicate incorrect operation and inadvertent operation of surge gas mode. The alarm will reset the timer that controls the final valve to ensure the delay times are respected in the TEG. The adopted option ensures that the delay time criteria is respected in any situation.

762. A second modification was implemented in order to reduce the flow rate of gaseous effluent in the TEG. Previously, discharge of effluent from the TEP to the TEU involved two stages – release of primary effluents from the TEP1 tanks and replenishment with water from the Demineralised Water Distribution System (SED). This resulted in a high volume (around 7,500 m^3) of gaseous effluent (mainly containing noble gases) with the associated flow rate (around 8.3 te/h) discharged to the TEG.

763. The modification to the TEP, allowing for simultaneous release of effluents and water replenishment, reduced the volumes of gaseous effluent discharged to the TEG, allowing the Xenon and Krypton isotopes to be retained for at least 40d/40h respectively [Ref 133].

764. Prior to the decay beds, gaseous effluent is dried. In the event that the flow increases and in order to prevent unavailability of the drier, design change CCSE5033 enables the flushing of nitrogen to regenerate drier. [Ref 129].

c) Evidence 112: Use of the Containment Inter-Space Ventilation System

765. The EDE maintains the annulus at a sub-atmospheric pressure during normal operations and following postulated design basis accidents, establishing an essentially leak-tight barrier against uncontrolled releases of radioactivity to the environment.

766. The maximum leak rate from the internal containment is 0.3 % vol/day at the design pressure and temperature.

767. The EDE system includes two redundant iodine trains (2 x 100%) supplied by two separate electrical trains as well as a HEPA filters to abate any radioactive material present in the Annulus.

d) Evidence 113: Decay of isotopes of krypton, xenon and iodine

768. **Table *6-3*** below presents the percentage of the activity remaining in the discharge of each isotope after the design delay time, with half-lives as published by the ICRP in [Ref 134]. This is converted into an effective decontamination factor and for the shorter half live radionuclides a considerable saving on activity discharged can be achieved. The rate of change is presented as a percentage. This represents the additional reduction in

activity over the space of an additional hour for krypton and day for xenon or iodine. The rates of change are relatively small which means that an increase in the decay period of the bed would result in only a very small improvement in performance. For example, a 50 % increase in the period of delay would result in a 0.02 % saving of krypton-88 and 0.47 % saving in xenon-133 discharged. It is therefore considered that the decay periods have been optimised.

Table 6-3 Decay of isotopes of krypton, xenon and iodine

Group	Isotope	Half-life	Half-life (days)	% remaining activity after delay bed*	Decontamination Factor	Rate of change
Krypton	Kr-85	10.72 y	3912.80	99.97	1.00E+00	0.002%
	Kr-85m	4.48 h	0.19	0.21	4.17E+02	0.000%
	Kr-87	76.3 m	0.05	0.00	1.70E+09	0.034%
	Kr-88	2.84 h	0.12	0.01	1.36E+04	0.001%
Xenon	Xe-131m	11.9 d	11.90	9.74	0.00E+00	0.584%
	Xe-133	5.245 d	5.25	0.51	1.73E+02	0.072%
	Xe-133m	2.188 d	2.19	0.00	2.32E+05	0.000%
	Xe-135	9.09 h	0.38	0.00	9.79E+30	0.000%
	Xe-138	14.17 m	0.01	0.00	-	-
Iodine	I-131	8.04 d	8.04	3.18	2.88E+01	0.286%
	I-132	2.30 h	0.10	0.00	3.02E+122	0.000%
	I-133	20.8 h	0.87	0.00	3.50E+13	0.000%
	I-134	52.6 m	0.04	0.00	-	-
	I-135	6.61 h	0.28	0.00	4.15E+42	0.000%

6.2.28 Sub-Argument 23: Process Gas Recirculation System

769. Noble gases that escape from fuel elements, or that may have been formed by fission of “tramp” uranium outside the fuel elements become dissolved, and circulate, in the primary circuit coolant. However, when the pressure is reduced, the gases will begin to come out of solution – this typically occurs in the tanks of the primary circuit RCV. Treatment of gaseous effluents from the various tanks and systems serving the primary circuit in the UK EPR^{TM} is carried out in the TEG. This is different to that used on French PWRs but uses best current methods developed for the German KONVOI design.

770. A key feature of the UK EPR^{TM} design that differs from French PWRs to date is the recovery of purge gas (nitrogen) that is compressed and then returned to the system for re-use [Evidence 112]. Thus, a large portion of gas is retained within the TEG for return to the various ullages and headspaces in the tanks from which it originated, maximising recirculation and minimising discharges. This retains the shorter-lived radioactive gases (mainly inert gases) to allow decay.

771. Primary coolant is continuously extracted from the primary circuit by the RCV to purify, store or degas the primary coolant in different auxiliary systems. All components of these auxiliary systems in which gases can be released from the primary coolant are connected to the TEG. All these components, tanks etc. are continuously flushed with nitrogen by TEG to process the released gases. For example, during normal operation, a portion

of the primary coolant is let-down into the RCV tank. Noble gases are removed from the primary coolant by degassing in the VCT.

772. To avoid leaks of gaseous effluents into the reactor and auxiliary buildings, a continuous nitrogen flow runs over the free volumes of the purged tanks and vessels, most of which are kept slightly below atmospheric pressure. The purge gas (nitrogen), after passing through the catalytic recombiner, is compressed and then returned to the system for re-use. Thus, a large portion of gas is retained within the TEGfor return to the various ullages and headspaces in the tanks from which it originated, maximising recirculation in a quasi-closed loop and minimising discharges. This retains the shorter-lived noble gases to allow decay prior to discharge to the environment [Ref 5].

773. The discharge of gaseous radioactive waste is therefore minimised within the UK EPR^{TM} design by maximising recycling of gaseous effluents providing an opportunity for the decay of shorter-lived radioactive gases.

a) Evidence 114: Nitrogen Purge Gas

774. The UK EPR^{TM} design differs from those of other 1,300 MWe units in its use of nitrogen instead of hydrogen in the VCT as a scavenging cover-gas. This design choice reduces the non-radiological risks associated with the use of flammable hydrogen gas but has the radiological impact of increasing the source term (and thus discharges) of carbon-14 in comparison with those reactors which do not use nitrogen for this purpose. The additional carbon-14 introduced as a result of this change has been assessed to be of the order of 10 %, based on the information presented in section 6.3.1 of Sub-chapter 6.3 of the GDA PCER [Ref 47], (where the 10 % addition is based on a normal operating concentration of 10 ppm for the use of nitrogen). There is some uncertainty on the additional discharges, as for all arisings of carbon-14, but the use of higher nitrogen concentrations would be expected to result in increased carbon-14 discharges.

775. The use of nitrogen is based on evolution of the design of PWRs, taking account of the experience of operating the KONVOI reactors in Germany which use nitrogen instead of hydrogen. This change reduces the non-radiological risks associated with the storage of large volumes of hydrogen, thereby enabling a reduction of the volume of stored hydrogen of 1000 m^3 (section 7.3.2 of Sub-chapter 6.3 of the GDA PCER [Ref 47]). No formal options assessment has been carried out and its inclusion in the UK EPR^{TM} design is based on benchmarking against world practice in PWR design and operations, as part of the UK EPR^{TM} environment design review, and review of non-radiological safety issues.

776. The use of nitrogen as a cover gas is considered to be the BAT for the UK EPR^{TM} for the flushing of components in the primary circuit, despite the modest addition to carbon-14 discharges that the change introduces (in comparison with other PWRs). Flushing of the system is necessary to achieve coolant degasification and also limits the hydrogen content in the system and connected components to less than 4 % (the Lower Explosive Limit for hydrogen) by volume (as discussed in section 3.4.1 of Sub-chapter 8.2 of the GDA PCER) [Ref 5].

777. Before tanks connected to the RCV undergo maintenance, they are swept with nitrogen in order to remove any accumulation of hydrogen and radioactive noble gases to the TEG. The vessel is also swept by compressed air (Service Compressed Air Distribution System (SAT)), discharged to the DWK prior to entering the vessel. In order to decrease the amount of gas used, and so minimise the gaseous discharge to TEG, the vessel is filled to the maximum level with demineralised water [Ref 68].

b) Evidence 115: Flushing of the Reactor Coolant System

778. The reactor coolant pumps are required for access during the mid-loop condition in outages. A design change has been introduced to allow the initial flushing of the RCP by nitrogen from the SGN and secondly of air with sufficient provision to prevent backflow of nitrogen into the SAT [Ref 135].

779. A control valve, in addition to a manual isolation valve, will be installed downstream both SGN and SAT supplies, in order to control the flow rates and operating pressures during the flushing process.

780. The RCP pressuriser is currently drained solely with nitrogen via the SGN during outage conditions. The proposed design will allow the initial draining of the RCP pressuriser with nitrogen and secondly draining with compressed air SAT with sufficient provision to prevent backflow of nitrogen into the SAT. To avoid particles being transported from the SAT to the SGN new filters are required to be installed at the SAT/SGN interface for both part of the modification.

6.2.29 Sub-Argument 24: Filtration of Gaseous Discharges

781. The UK EPR^{TM} design incorporates a number of filtration techniques to ensure that the radioactivity of the gaseous discharge stream is minimised, during both normal operation and accident conditions. There are a number of gaseous radionuclides which can be released within the gaseous waste discharge stream including tritium, carbon-14, iodines, noble gases, and other fission or activation products. If discharged to the environment unabated, these particulates and nuclides could present consequences in terms of radiation doses.

782. The standard technique for the removal of particulate from gaseous effluents collected by high volume air-extract systems in nuclear installations involves the use of HEPA filters (efficiency 99.95 - 99.999 %) [Ref 136]. During normal operations, iodine and any particulate fission or activation products will be abated by filtration. However, the amount of radioactive particulate requiring abatement during normal operation is relatively small. Whilst HEPA filters are effective in reducing gaseous radioactive discharges of particulate during normal operations, their principal function is to provide safety and environmental protection in response to an event involving the release of significant particulate material, such as a fire involving radioactive waste materials or a fuel handling event; where extraction of air for environmental discharge is required. The use of HEPA filtration for high volume air-extract systems in nuclear installations is considered best practice and is widely used throughout the world [Ref 5].

783. The following ‘best practice’ gaseous filtration techniques are implemented within the UK EPR^{TM} design:

- Pre-Filters – Prior to gaseous effluent being routed through the HEPA filters, the pre-filter captures large airborne particulates, preventing filter damage and prolonging the life of the HEPA filters placed further downstream [Evidence 114].
- HEPA Filtration – HEPA filters are incorporated into all radiation controlled areas, including the HHI in order to remove particulate actinides in the event of an accident, as well as particulates as a result of unplanned but not unexpected contingencies that may occur as part of normal operation. A decontamination factor of 1,000 is required for the effective operation of HEPA filtration. When new, the HEPA filters incorporated into the UK EPR^{TM} design have a decontamination factor of at least 3000, corresponding to a 99.97 % efficiency [Ref 137]. HEPA filters are one of several ‘best practice’ techniques used for gaseous abatement throughout the international nuclear sector [Evidence 115].
- Iodine Filters – Following HEPA filtration, the gaseous discharge stream can be re-routed via iodine filters, in the event that activity levels are detected above a certain level during normal operations. Iodine filters may also be implemented during emergency conditions, isolation of the reactor building atmosphere or during purging of a Safeguard Building (HL) due to a breach in the RIS. Iodine filters are considered to be one of several ‘best practice’ techniques for gaseous abatement. This technique is considered to be relatively mature and it is unlikely that new technologies would significantly enhance their effectiveness [Ref 103] [Evidence 116].

784. In conclusion, filtration is predominantly put in place in order to abate radioactive particulate within the gaseous discharge system during accident conditions. However, filtration does provide abatement during normal operation and when operated together with decay storage, the gaseous abatement system for SZC is

considered to be best practice in minimising the amount of radioactivity discharged or disposed of to the environment in the gaseous waste stream.

a) Evidence 116: Use of Pre-Filters

785. The pre-filters used for extraction, upstream of the HEPA filters, are designed to lengthen the service life of HEPA filters by filtering large particles from the air flow.

786. In addition, filter on the air inlet are used to minimise the non-active particulate entering the building that could enter the building ventilation system and impact the mass loading of the gaseous effluent.

787. If significant amounts of gaseous radioactive products, particularly Iodine, are released during accident conditions the normal filter beds would become highly radioactive and as a result access to the rooms containing the iodine filters would become difficult for personnel. Accordingly, a separate filtration route is required to capture the iodine under severe accident conditions.

788. A substantial pre-filter has been introduced, which can be selected in accident conditions from the Main Control room. The filters will be on each train of the EDE, EBA and DWL systems. The filters will have to be heavily shielded to prevent personnel dose being significant. A Technical Review has assessed that the level of contamination of the pre-filters will be low, and so disposal will not be a significant issue [Ref 139].

b) Evidence 117: Use of HEPA Filtration and Iodine Filters

789. The potential for radioactive particulate is minimised at source and based on operational experience the radioactivity content on spent filter arisings is not generally expected to be significant, thereby indicating that measures taken to minimise particulate discharges at source are effective. HEPA filters will be changed, where practicable, upon meeting high differential pressure advised by the manufacturer, which will be detected through a site maintenance and monitoring schedule. Choices for the selection of HEPA filter manufacturer will be based upon a procurement specification consistent with relevant performance standards.

790. HEPA filters are installed on all HVAC systems servicing the UK EPR^{TM} nuclear island and auxiliary buildings (radiation and contaminated controlled areas) where there is a potential for radioactive particulate in extract air-streams. The HR incorporates internal particulate and iodine filtration systems (EVF) which can operate at power to reduce radioactivity in air without the need for continuous extraction and help to maintain air pressures in relevant plant areas to control air flow and environmental conditions. The system is also used to guarantee negative pressure in the rooms that have a risk of iodine presence [Ref 140], both to ensure that any particulate will enter the extract system, and that any leaks in the containment cause air to be drawn into the room, rather than leak out.

791. Pre-filters designed to capture particulate that might damage HEPA filters are used and this is standard practice. Inlet HVAC filters are installed to minimise the presence of particulate in air subsequently extracted for discharge, thereby reducing the non-radioactive particulate burden on HEPA filters and maximising their operational life. The HEPA filter type chosen for each system will depend on the environmental and flow-rate conditions anticipated but the vast majority of filters will be of standard design for general HVAC operation.

792. The HEPA filtration systems for UK EPR^{TM} will meet industry codes of practice for the testing, design and operation with particular reference to UK standards such as NVF/DG001 (An Aid to the Design of Ventilation of Radioactive Areas) [Ref 137], which is considered to be consistent with comparable standards in France. It can be considered that the systems used for UK EPR^{TM} are consistent with those used for existing installations in the UK and employed on most other nuclear installations [Ref 5]. The responsible designer undertook a type assessment for HEPA filters [Ref 218] which considered best practice for HEPA filter design in the HPC design. The decision was made to retain the usage of rectangular HEPA filters, compared to circular.

793. HEPA filtration and iodine filters are two ‘best practice’ techniques which have been implemented within the UK EPR^{TM} design in order to ensure abatement of radioactive gaseous discharges during both normal operation and accident conditions. HEPA filtration and iodine filters are inextricably linked due to the nature of the

ventilation system, whereby gaseous ventilation effluent can be passed through iodine filters following HEPA filtration if activity measurements exceed a certain level.

c) Evidence 118: Use of filtration of Gaseous Effluent by the Ventilation Systems

794. The gaseous ventilation effluent processed by the DWN comes from contamination controlled zones in the HN, the HL's, the Effluent Treatment Building and the Fuel Building (apart from incidents); and from purging the HR when the unit is shut down and the reactor head removed for refuelling outage (EBA high flow). This circuit has an extraction plant connected to the stack with pre-filters and HEPA filters. If required, the discharge can also be directed through carbon bed filters to allow removal of iodine isotopes.

795. The extraction plant treatment trains comprise:

- 6 filtration trains with a unit flow rate of 20,000 m^3 h^{-1}, three for output from DWN ventilation, two for Fuel Building ventilation and one for HL ventilation;
- 1 x 25,000 m^3 h^{-1} filtration train for the high-flow EBA;
- 4 exhaust fans;
- 4 iodine traps, each with its own reheater. If iodine is detected in the premises exhaust ducting, the airflow is automatically sent through these iodine traps; and,
- 4 booster fans to make up the additional pressure loss.

796. The basic function of the filters complies with European Standard NF EN 779. It is widely used across the French fleet; it is a proven technology which combined with the use of French fleet good practice, minimises waste arisings. The use of pre-filter and HEPA filter on the UK EPR^{TM} is considered to be BAT, as described in Chapter 8 of the GDA PCER [Ref 47].

797. The filters are changed when a pressure difference (ΔP) reaches a set limit (filter blinding) or when a plant operational activity limit is reached. This means that the filters are not changed at a regular frequency, but rather as and when required, hence the filters will be used to their full capacity and not prematurely wasted. Combined with the use of pre-filters to prolong the HEPA filters life and the iodine traps not being systematically used, minimises solid waste arisings associated with filtration and is part of the application of BAT. All of the ventilation systems for the HN, HL, and Fuel Building rooms can be routed to Iodine Traps prior to discharge. This is in contrast to the current 1,300 MWe plants where only selected plant areas in the HN can be so routed. In addition, in the UK EPR^{TM} design, all the rooms with special cells (two for the Fuel Building, three for the HN, one for the HL) pass through HEPA filters that can be routed to the iodine traps.

798. The design of the active HVAC systems will facilitate the periodic efficiency testing of the filters [Evidence 211]. This will allow identification of issues associated with fitting of a new filter, and will allow assessment of failed filter media.

799. The KRT, automatically measures the activity and hence routes the gaseous effluents via the iodine traps, if activity measurements exceed a set level. The detection is based on the beta global activity measure, as a high activity of noble gases indicates a possible discharge of iodine. The effluents can, however, also be routed manually by the operator, should a management decision to do so be warranted. This, for example, may be in anticipation of a high activity measurement.

800. Other circumstances when the gaseous effluent may be rooted via the iodine traps are as follow:

- In emergency conditions.
- Isolation of the reactor building atmosphere.
- Purge of a HL due to a breach in the RIS.

801. The EBA (reactor building internal purge) iodine traps are used during normal power operations.

802. A BAT assessment was produced to demonstrate that the specification for the charcoal and charcoal challenge material for the Iodine filtration units represents BAT [Ref 130]. From this assessment a charcoal with the characteristic similar to charcoal sourced from coconut shells, impregnated with either 1% Potassium Iodide (KI) or 2-5% Triethylenediamine (TEDA) is considered to be the option that demonstrates BAT, provided that the requirement of 99% efficiency is met. A non-powdered charcoal should be selected, in order to minimise dust generation. OEF from the EDF Energy Nuclear Generation fleet is that the charcoal should be virgin material, re-activated or re-impregnated material should not be used. These requirements are to be incorporated into procurement specifications for the SZC project, without specifying the exact charcoal type, so as not to foreclose options.

d) Evidence 119: Abatement of Gaseous Effluent from the Primary Coolant

803. If required, the DWN can also provide further clean-up and treatment of primary gaseous effluent from the TEG. This would then be monitored and discharged via the stack.

804. Design change T1EPUK100004 [Ref 81] details changes made to the RPE18 to prevent excessive dose to operators. RPE18 collects primary effluents as a result of overpressure of safety valves from systems in the HN and HK (primarily TEG and TEP). The system is protected by a safety valve (RPE1891VP) that originally would have discharged the gaseous/liquid effluents into the TEP maintenance and inspection room (HNX0320ZL); this presented an unacceptable safety risk to operators who may be in the room. The design change involves redesign of the RPE18 to add a liquid/gas separator to redirect any gaseous discharges to the DWN plenum instead of the maintenance room, the liquid to continue to go to the TEP tanks.

805. The design change results in potential for a significant discharge of unabated gaseous effluent to the environment in the event of an over pressurisation of the RPE18 safety valve. The frequency would be expected to be low; another design change (T1WITUK10456) [Ref 81] aims to provide significant mitigation of the frequency by reducing transients in the TEG that could result in an over pressurisation event. A gaseous discharge via the DWN would however result in a low impact to the environment; furthermore, a BAT assessment [Ref 80] quantified the expected activity of noble gases discharged to be 2.71-8.88 TBq compared to the proposed annual limit of 45 TBq and justified the design change to mitigate the more significant risk to workers.

e) Evidence 120: Abatement of Gaseous Effluent from the Secondary Circuit

806. Small leaks may occur between the primary and secondary circuit through which tritium and other radionuclides may migrate into the secondary circuit and condensed secondary water. With low pressure in the condenser wet well during operation, some radioactivity can therefore appear in the main condenser off gas. This is collected in the CVI, and then sent to the DWN, where it is passed through a HEPA filtration before being discharged into the stack.

f) Evidence 121: Use of the Containment Sweep Ventilation System

807. The EBA manages the supply, extraction and filtration of ventilation air from the HR. It includes a filtration system with pre-filters, HEPA filters and iodine traps, which are used if high iodine levels are detected. The gaseous effluent is discharged through the HN stack.

808. The EBA is generally not required whilst the reactor is at power. During normal plant operation, when the access to the HR service area is required, EBA low-capacity is started up to sweep this service area atmosphere two day before access. EBA continues the air sweeping during all the access period to guarantee an air contamination level compatible with personnel access. EBA low-capacity carries out an atmosphere mini-sweeping of the HR service area whenever necessary and supplements EBA High-capacity operations during plant shutdown. The EBA high-capacity line is put into service for sweeping the reactor building during plant shutdown states.

g) Evidence 122: Abatement of Gaseous effluent from the Effluent Treatment Building Ventilation System

809. The DWQ conditions, extracts and filters the Effluent Treatment Building ventilation air. This now includes two new service galleries (HGQ and HN – Tanks Liaison Gallery (HGV)) which provide a physical link for the transfer of fluids between building HQB, HQC and HXA respectively. The DWQ system combines subsystems 9DWQ (which covers HQA/HQB and the HGQ/HGV galleries.) and 2DWQ (which is a separate HVAC system that serves HQC).

810. The 9DWQ includes a filtration system with pre-filters, HEPA filters and an iodine trap. If high levels of iodine are detected, based on the measure of beta global activity, the effluent will be routed through the iodine trap. The HVAC systems in the DWQ, in addition to the DWN and EBA's, were assessed as part of an Environmental Optimisation Study (EOS) in order to determine BAT to ensure that radioactive discharges are minimised and to ensure robust and reliable testing of HEPA filters and Iodine traps [Ref 141].

811. The discharges from the DWQ are routed to the HN stack.

6.2.30 Claim 2, Argument 14: Consideration of abatement techniques for removal of Carbon-14 and tritium

812. It is important to note that whilst noble gases, iodines and other fission or activation products are abated within the gaseous discharge system, both tritium and carbon-14 are not. Reasons for the lack of gaseous abatement, and alternative methods, are:

- Tritium - Although there are treatment processes which could, in theory, be used to reduce liquid tritium discharges from an UK EPR^{TM}, the benefits in reduced public exposure from the use of such processes are considered to be grossly disproportionate to the cost and resources of their implementation (which would include the costs of having to dispose of all of the associated secondary solid wastes).
- Carbon-14 -The potential use of a range of gaseous abatement techniques have been explored for the abatement of carbon-14, but ultimately it was considered that these were not appropriate for implementation within the UK EPR^{TM} design. This was largely due to the costs and resource requirement of their use being considered grossly disproportionate to the benefits achieved, which is consistent with international experience of PWR operations.

813. Where gaseous abatement techniques have not been implemented for tritium and carbon 14 gases, partitioning and a number of other techniques have been taken into consideration. Where the cost of implementing such techniques is grossly disproportionate to the benefits gained, these techniques have not been implemented within the UK EPR^{TM} design.

a) Evidence 123: Consideration of Other Techniques for removal of carbon-14

814. Carbon-14 provides the greatest contribution to the critical group dose of any single radionuclide. Therefore, opportunities to minimise the dose from carbon-14 should be explored. Notwithstanding this, the dose from gaseous and liquid discharges of carbon-14 to the most exposed age group of the critical group is in the order of a 12 µSv y^{-1}, with 9.5 µSv y^{-1} attributable to liquid discharges and less than 2.5 µSv y^{-1} from gaseous discharges [Ref 10]. A number of technologies for the abatement of carbon-14 have been assessed for their viability (and whether they are BAT) for use at nuclear power plants.

i. Alkaline Scrubbing

815. In this method, off-gas would need to be oxidised to ensure all carbon-14 is present as carbon dioxide and then scrubbed to remove the carbon dioxide. The scrubbing medium may be a liquid (typically sodium hydroxide

solution), a slurry (typically lime) or a solid form (typically using lime or barium hydroxide). When a liquid medium is used, the spent liquid is treated to precipitate the carbon-14 as a solid form (typically using lime or barium hydroxide).

816. Work on dry barium hydroxide scrubbers for treating PWR and BWR off-gas has been performed in the US. This demonstrated that the process is capable of high CO_2 removal efficiencies and high reactant utilisation, and has acceptable operational characteristics at near ambient conditions. There is no information available however to suggest that the process has been taken forward and fitted to an operational reactor [Ref 5].

817. The removal of carbon-14 from gaseous streams is discussed in IAEA Technical Report 421 [Ref 142]. It notes that most of the available techniques, remove carbon-14 as CO_2. The main disadvantage of these methods is that a large amount of secondary waste is generated, particularly if the waste stream contains large amounts of $^{12}CO_2$. A number of issues would need to be resolved before such a technique could be considered for application on an operational reactor, including the oxidation of methane and other organic components to carbon dioxide, the handling of the secondary wastes, subsequent conditioning and packaging of the wastes, radiation doses to workers and other safety issues. The cost effectiveness of the application of these techniques in relation to the radiological impacts of gaseous discharges remains to be demonstrated.

818. Although these alkaline scrubbing processes, have been investigated for use on PWRs none have been fitted on operational reactors. On this basis the use of alkaline scrubbing is not considered to be BAT for SZC and is not given further consideration.

ii. Fluorocarbon or Ethanolamine Absorption

819. In this method, off-gas is passed through a cooled fluorocarbon solvent. $^{14}CO_2$ is absorbed and subsequent stripping yields a stream of concentrated $^{14}CO_2$. This needs to be preceded by an oxidation stage to ensure all carbon-14 is present as CO_2. Pilot-scale facilities have been operated in US and Germany. Scrubbing with ethanolamine is one method identified for the removal of CO_2 from gaseous streams used in the chemical industry. It is also discussed in IAEA Technical Report 421 [Ref 142]. This involves absorbing the CO_2 into an ethanolamine solution and the solute is then steam stripped out of the scrubbing solution, thereby producing a gas stream richer in CO_2. A reduction factor of 2 to 7 is claimed when treating initial concentrations of 3 to 15 % CO_2. An additional product solidification technique would be required in addition to either of these techniques to prevent discharge of carbon-14 to the environment.

820. The development of this waste management option in the nuclear industry has been focussed on providing a treatment solution for discharges from reprocessing, which potentially involves much higher activity levels of krypton-85 and carbon-14. The suitability of this method for the lower concentration of carbon dioxide in gaseous waste streams in the UK EPR^{TM} (< 0.1 %) and other PWRs is not demonstrated and, as with alkaline scrubbing, a number of issues would need to be resolved before the technique could be considered for use on an operational reactor. This method has not been adopted on any operational reactor and cannot be considered to be world best practice and is thus not given further consideration [Ref 5].

iii. Molecular Sieve Adsorption

821. For this method, off-gas needs to be oxidised to ensure all carbon-14 is present as $^{14}CO_2$. Oxidised off-gas is passed through a molecular sieve, which captures the $^{14}CO_2$. Concentrated $^{14}CO_2$ is subsequently desorbed and captured in an alkaline scrubber (liquid, slurry or dry, see above).

822. This method can only be used with low concentrations of CO_2 (<1 to 2 %), which correspond with the level of <0.1 % CO_2 in UK EPR^{TM} waste gaseous discharges. This method is reported not to be suited to industrial scale use and there remains the problem of managing the trapped carbon-14 (in the gaseous CO_2). It could be stored as solid waste in saturated molecular sieves, or the sieves can be regenerated but this still would leave the issue of managing a concentrated gaseous CO_2 waste stream that would have to be captured in an alkaline scrubber (liquid, slurry or dry).

823. For efficient and reliable use of molecular sieves a constant environment is required, i.e. stable temperatures and stable pressures. This is not the case for the UK EPR^{TM} gaseous waste stream, where flow rates can vary from 0.2m^3/h (stable running) up to 100 m^3/h, i.e. a factor of 500.

824. Some development work has been undertaken on this treatment option in the nuclear industry (IAEA Technical report 421 [Ref 142]) but no pilot or prototype installations have been constructed. This management option is not proven on a PWR, cannot be considered to be world best practice and is not given further consideration [Ref 5].

iv. Cryogenic Distillation

825. Noble gases, water vapour and carbon dioxide can be frozen out of a gaseous waste stream. Fractional distillation at liquid nitrogen temperatures produces a concentrated stream of carbon dioxide (including $^{14}CO_2$), which can be removed from the waste. This technique has only been used on small scale demonstration installations. This option has not been developed sufficiently to be a credible option for application on an operational reactor and is therefore not given further consideration [Ref 5].

v. Gas Hydrates

826. [Ref 5] describes this process as being at the R&D phase, with a single notable use, on offshore gas/oil platforms, which release very high CO_2 concentrations. It is not considered suitable for use for applications where the CO_2 concentration is low, such as for the UK EPR^{TM} gaseous waste stream, and is not given further consideration on this basis [Ref 5].

vi. Other Methods

827. Several other methods of separating and fixing carbon-14 from nuclear plant's operational releases of carbon-14 in carbon dioxide form are being investigated. These include decomposition of CO_2 using microwave discharges (Journal of Nuclear Science Technology 37 [Ref 143]) and isotope separation of CO_2 using plasma chemical reactions (Journal of Nuclear Science Technology 38 [Ref 143]). Once separated, it is envisaged that the elemental carbon-14 would be stored as elemental carbon. However, these techniques are currently in the early stages of development and have not been demonstrated at an industrial scale or used on a PWR [Ref 5].

b) Evidence 124: Consideration of other techniques for removal of tritium from liquid discharges

828. This position is strengthened by the fact that none of the treatment processes are currently used anywhere on an operational PWR and would need significant development work for such use. There are currently no processes implemented on an industrial scale for the treatment of tritium in liquid phase for a PWR, and therefore all liquid tritium produced is discharged. Examples of these treatment processes are outlined below. In addition, the dose accruing from liquid discharges of tritium from SZC to the representative person is less than 0.02 µSv y^{-1}.

vii. Detritiation and tritium removal/separation

829. A number of techniques have been developed for tritium removal or the detritiation of heavy water (for Heavy Water Reactors), including electrolysis and catalytic exchange, and fractional distillation. Tritium removal from light water requires larger stripping and recovery factors than for heavy water. A feasible tritium removal process would require a high isotopic separation factor. IAEA Technical Report No 421 identifies the hydrogen-water chemical exchange process as having the required isotopic separation factor and which is suited to a water feed.

830. IAEA Technical Report No 421 [Ref 142] also reports a study of methods for the detritiation of light water containing very low concentrations of tritium. Six technologies were judged to be uncompetitive or impractical: water distillation, electrolysis, bithermal ammonia hydrogen, monothermal ammonia hydrogen, laser isotope

separation and water permeation. The processes that showed potential for possible development included chemical exchange: combined electrolysis and catalyst exchange, Girdler sulphide and bithermal hydrogen water exchange. No information is available to suggest that any of these have been progressed or used anywhere on an operational PWR.

831. Isotopic retention is a process in which selective migration of specific radioisotopes is catalysed by an electrochemical process. However, development of this mechanism is only at an early stage of development.

viii. Decay storage of liquids

832. The half-life of tritium (12.3 years) means that it is not possible to store all the liquid tritium produced for decay, as the volumes would be too large. This would also increase the risk of uncontrolled gaseous tritium discharges due to evaporation from the discharge tanks.

ix. Evaporation

833. Evaporation is not an option since the tritiated water would carry over with the non-tritiated water to be condensed so most of it would be present in liquid form.

x. Conversion of tritiated water to solid waste

834. Filtration is not applicable to abatement of tritium in liquid waste. The tritiated water could be cemented. This would produce very large volumes of solid waste which would need to be disposed of and there is uncertainty as to the effectiveness of the immobilisation of tritium.

c) Evidence 125: Consideration of other techniques for removal of tritium from gaseous discharges

835. Similar conclusions apply to discharges of tritium in gaseous form. The dose accruing from gaseous discharges of tritium from SZC to the representative person is less than 0.3µSv y^{-1}. Potential processes to reduce gaseous effluent discharges are:

- Collection and retention of effluent gases, to allow radioactive decay, is impracticable due to the long decay time required.
- Filtration is not applicable to abatement of tritium in gaseous waste.
- The possible use of molecular sieving in which gas is oxidised and the tritiated water which is produced collected by the sieve. The sieve is then disposed as solid waste, or the water may be desorbed and discharged as liquid effluent.
- Packed bed or plates. This technique can only be used if the intention is to generate a dilute tritium stream for direct discharge. This would divert tritium from gaseous to liquid discharge, but given the very low ratio of tritium being discharged by the gaseous route (2-3 %) and the inefficiency of the process, the benefits achieved would be grossly disproportionate to the costs of implementation.

6.2.31 Claim 2, Argument 15: Minimisation by the Decay Storage of Solid Radioactive Waste

836. Decay storage takes advantage of radioactive decay in changing the category of a waste, thereby enabling use of alternative and/or available disposal routes and is particularly useful where ILW decays to LLW. It is a robust strategy for waste management as it does not require any mechanical or chemical waste treatment, and thus does not generate any significant secondary radioactive discharges during the storage period. The site operator must simply ensure that the waste is securely and safely stored for the period needed for decay.

837. With regard to the UK EPR™, some of the waste generated during operations is classified as ILW at the time of generation. The dominant radioisotopes at the time of generation in these wastes are likely to be cobalt-60 (half-life of 5.27 years), caesium-137 (half-life of 30.2 years) and iron-55 (half-life of 2.7 years). The design lifetime of the HHI for ILW storage is up to 100 years, with operational wastes being interim stored for a maximum period of between 40 years (for wastes arising at the end of operations) and 100 years (for wastes arising near the beginning of operations). This storage period is greater than the half-lives of the dominant radioisotopes within most operational wastes streams at the time of waste generation. The decay curves for the isotopes named above show that both cobalt-60 and iron-55 reduce to a fraction of a percent within 60 years and caesium-137 reduces to 10% of the original activity within 100 years [Evidence 124].

838. The Review of ILW Decay Storage Strategy [Ref 144] contains decay curves for UK EPR™ dry active waste and spent water filters. These wastes contain the isotopes above and are prime candidates for decay storage as they decay significantly within the aforementioned time period [Evidence 125].

839. Decay storage can take place with or without the waste having undergone immobilisation. The decision whether or not to immobilise waste prior to decay storage depends on the following considerations:

- Dose to operators.
- Ensuring passive safety over the period of decay storage.
- Availability of treatment and disposal options for un-immobilised waste.

840. The Review of ILW Decay Storage Strategy [Ref 144] provides justification for why only Dry Active Waste (DAW) is to be stored un-immobilised. This is due to the waste being dry, decaying in relatively short timescales and benefitting from the availability of a range of treatment disposal options such as incineration and metals recycling following decay. Sludges and filters however require encapsulating to make the passively safe during storage due to their wet nature and currently only have one available disposal route which requires them to be encapsulated to meet Waste Acceptance Criteria (WAC). Immobilising the waste also support the ALARP argument for these wastes as it adds shielding and avoids double handling of the raw waste. The ILW building will be designed to accommodate the amount of waste expected over the lifetime of the site. It will be designed to take into account worker safety and security of the material within the building. As the name suggests, the ILW building is currently being designed to accept this level of waste. However, there may be opportunity to decay lower level wastes to make use of alternative waste management options in the future.

841. There are many benefits associated with the reduction in activity of solid wastes, by using methods of decay storage. These include working in accordance with the waste hierarchy (opening up routes which have the potential to reduce volume, reducing the risk from the material), reducing activity without the production of secondary wastes, reducing potential dose to workers and ultimately disposing of the waste in a way which results in the least impact upon the environment.

a) Evidence 126: Evidence for the decay of cobalt-60, caesium-137 and iron-55

842. The radioactive decay during interim storage of the ILW due to its composition of short lived radionuclides can reduce the final quantities of ILW requiring disposal. Some of this waste could be reclassified as LLW [Ref 145].

b) Evidence 127: Evidence for the decay of dry active waste and spent water filters

843. The Review of ILW Decay Storage Strategy Report [Ref 144] shows the radioactive decay characteristics for the spent water filters arising from operation of the UK EPR™ which, pessimistically, would be ILW at the time of generation. The graph is the total activity for all radionuclides predicted to be present in this waste stream. The primary contributors to the total initial radioactivity of this particular waste are cobalt-60, caesium-137 and iron-55. The levels of radionuclides with longer half-lives are present at levels below the Low Level Waste Repository (LLWR) threshold of 12 GBq te^{-1} beta-gamma therefore this waste decays to LLW within a few decades. Long lived radionuclides are present in quantities above the thresholds for exemption and therefore

controlled decay storage to levels where the exemption provision can be applied is not feasible. It is assumed that a disposal route will be available for waste (formally VLLW) via an exemption provision, throughout the operational and decommissioning phases of SZC, as described further in the RSR Permit Application Head Document [Ref 1].

844. The Review of ILW Decay Storage Strategy Report [Ref 144] shows the decay characteristics of ILW DAW. With this waste it is cobalt-60 and iron-55 that dominate the activity over the first few years. These decay significantly over the first decade after waste generation, allowing the waste to be reclassified as LLW after approximately ten years.

c) Evidence 128: ILW Decay storage

845. Before sending ILW off site for disposal, there is a UK requirement to allow ILW to decay on-site to LLW where reasonably practicable. This can then be disposed of as LLW which minimises the amount of ILW for disposal. In France this practice is not followed so the UK EPR^{TM} at SZC has been modified with the HHI to allow for this.

846. ILW waste is managed as detailed in the SZC Integrated Waste Strategy [Ref 8] [Ref 135]:

- Ion exchange resins are polymer encapsulated into C1 packages.
- Filters are encapsulated into 500L drums.
- Sludges are encapsulated in 500L drums.
- DAW is placed unconditioned into a 500L drum.

847. All ILW packages are transferred to HHI for storage. Packages that decay to LLW are removed from HHI and transferred for disposal via the most appropriate route. This decay storage strategy results in a significant reduction in the volume of waste disposed of as ILW. The optioneering work which provides justification of the strategy is presented in [Ref 144].

848. A review of the ILW Decay Storage Strategy [Ref 144] determined that all non-resin ILW will be stored and disposed of in 500L drums rather than use C1/C4 casks as overpacks. This strategic decision has been justified as showing optimisation of the process and agreed with regulators [Ref 144] subject to ongoing work required to secure updated disposability agreements for disposal to the LLWR and to complete the Letter of Compliance (LoC) work for ILW wastes.

849. The HHI concept design has since reviewed the expected waste volumes at SZC based on OEF from the French fleet. This review concluded that the store is to be built in two phases the first store with capacity for the anticipated arisings during the first half of operation and a second store to cover the second half of operation. The capacity of the second store (if required) will be based on actual waste arisings during the initial years of operation allowing the required capacity to be predicted with more accuracy.

850. Given that HHI is a new building for both HPC and SZC (compared to FA3), a Baseline Environmental Summary for the building is captured as a planned assessment on the open point register.

6.3 Claim 3: SZC Co. Shall Minimise the Volume of Radioactive Waste Disposed to Other Premises

851. The information presented under Claims 1 and 2 indicates that considerable efforts have been expended to minimise the production of radioactive wastes and to minimise the radioactivity of those discharged to the environment. However, the operation of SZC will inevitably create some wastes that will require disposal to other premises. The UK EPR^{TM} has been designed to employ features that concentrate the radioactivity in these wastes and therefore reduce the volume that subsequently requires disposal to other premises. Taken together these features demonstrate that the following requirements will be met:

- Condition 2.3.2(b) of the proposed standard template of the RSR environmental permit [Ref 20] states that:

"The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to minimise the volume of radioactive waste disposed of by transfer to other premises"

852. The approach also demonstrates that the following Policy Principles have been taken into account during this stage of the programme:

- The UK Radioactive Discharge Strategy 2009-2030 [Ref 23] preference for concentrate and contain radioactive waste rather than dilute and disperse.
- The UK Policy for the Long-Term Management of Solid Low Level Radioactive Waste [Ref 147] which encourages the minimisation of waste arisings that will require subsequent disposal to dedicated LLW facilities.
- Principle RSMDP3 of the RSR - Environmental Principles: Use of BAT to minimise wastes [Ref 21], which states:

"BAT should be used to ensure that production of waste is prevented and where that is not practicable minimised with regard to activity and quantity"

853. It is important to recognise that it is sometimes necessary to balance the preference for and desirability of concentrate and contain against the potential to generate volumes of solid waste which are disproportionate in comparison with the impacts of disposal of liquid and/or gaseous wastes and the non-radiological environmental impacts of the measures needed to concentrate and contain wastes such as energy consumption. The selection of appropriate segregation, characterisation, sentencing and disposal through the application of BAT aims to balance these considerations. It is also important to understand that the operator may select options that do not necessarily minimise the volume disposed of from the site but ultimately result in a reduction in the volume of waste disposed in dedicated LLW facilities, such as the use of incineration and high-force compaction.

854. The design of the power station proposed for SZC contains a range of features that contribute to substantiating this claim. These features are presented in the arguments that follow this claim. Those that are considered particularly important to this stage of the programme are:

- techniques that will reduce the volume of secondary solid radioactive wastes generated during operation and eventual decommissioning;
- abatement techniques have been selected on the basis of the high efficiency with which they remove radioactivity per unit volume of solid waste that will require disposal;
- volume reduction techniques that improve the efficiency of solid waste disposal routes; and,
- selection of the optimal disposal routes for wastes transferred to other premises.

855. Taken together, these features are expected to minimise the volume of the radioactive waste discharged to the environment. This will contribute further to reducing the associated impacts from proposed operations at SZC.

856. Figure 6-10 shows the structure of the Claim, Argument and Evidence.

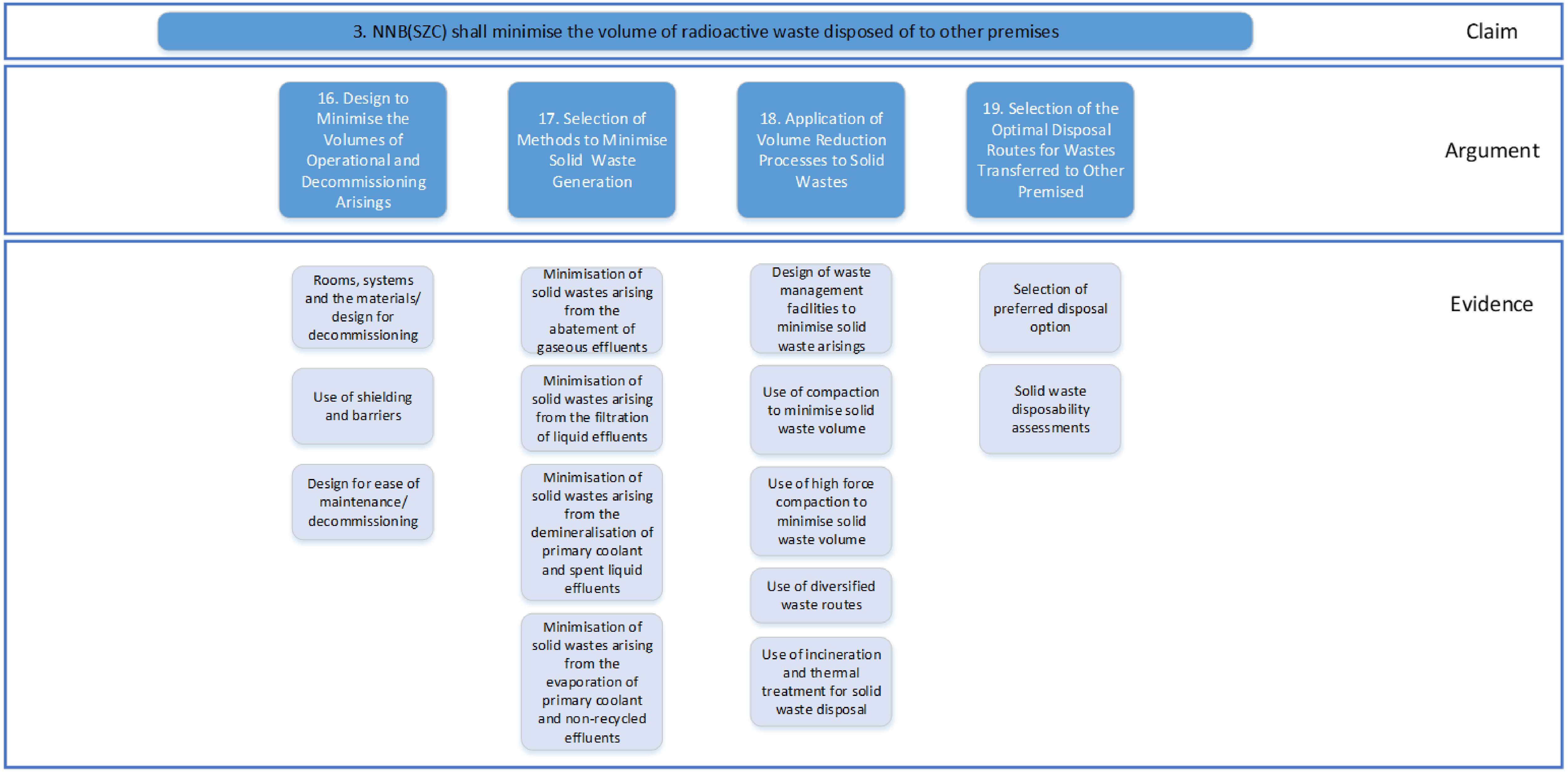


Figure 6-10 Claim 3 Structure

6.3.1 Claim 3, Argument 16: Design to Minimise the Volumes of Operational and Decommissioning Waste Arisings

857. Key factors affecting the volume of radioactive waste generally relate to features that will contain the waste as close as possible to the point where it was generated, wherever possible preventing it from contaminating otherwise non-radioactive items of plant, equipment and building structures. This concentrates the contamination such that there are smaller volumes of higher activity wastes requiring disposal. These factors are applicable both to operational waste arisings and the wastes produced at final decommissioning of the plant.

858. The UK EPR^{TM} design incorporates a number of features which minimise operational radioactive waste arisings and facilitate the decommissioning process. Such features represent an important aspect of environmental optimisation for SZC and support the claim that all efforts have been made to minimise the volume of radioactive waste requiring disposal to other premises. The main relevant design features can be grouped as follows:

- Improved fuel use and improved fuel cladding integrity: a reduction in the overall quantities of fuel used per unit of electricity generated as a result of improved fuel efficiency measures should minimise both operational and decommissioning radioactive waste volumes. It is anticipated that the reduced number of refuelling operations and the resulting reduced volume of spent fuel requiring storage and management will result in the generation of lower volumes of radioactive waste per unit of electricity generated. Further information on the measures adopted in the UK EPR^{TM} design to maximise the efficiency of fuel use are provided under [Argument 2]. Efficiency of Fuel Use Improved fuel cladding will reduce contamination of the circuit with fission products which will be of benefit in both operation and decommissioning and is discussed under [Argument 1].

- Reactor system design and optimisation of neutron shielding: Neutron shielding is utilised between the core and the reactor vessel to reduced irradiation of the steel and reactor compartment. The reactor is designed to minimise activation products and circuit contamination

- Minimisation of contamination build up in “retention areas” of process plant: the systems/process plant within the reactor core, the NSSS and ancillary systems are designed to minimise retention areas and voids and maximise drainage. In a poorly designed facility, materials can accumulate in retention areas, potentially causing corrosion and increasing the spread of contamination throughout the reactor, this in turn increasing worker doses and the activity and volumes of solid waste at decommissioning. Some examples of the type of UK EPR^{TM} design features to assist in this area are described further [Argument 9];

- Rooms, systems and materials used: specific measures have been taken in order to minimise the creation, transportation and deposition of contamination and to minimise the contamination/activation of rooms, systems and materials. Materials have been chosen based on their likelihood to become radioactive, either by activation or by the deposition/absorption of contamination. Wherever possible equipment will be designed to be easy to clean (i.e. to remove surface contamination) and be easy to disassemble (to allow separation of contaminated components) to aid maintenance and decommissioning, reducing both radiological dose to workers and volumes of solid radioactive waste requiring disposal. The materials of construction are discussed under [Argument 4].

- Maximisation of leak tightness: an important part of minimising the volumes of radioactive wastes requiring disposal, is to contain any contamination as close as possible to its point of origin. Within the UK EPR^{TM} a number of features have been incorporated within the design in order to “maximise leak tightness" to effect this containment. Further information on the relevant design features to ensure containment within the various rooms and systems is provided under [Argument 9].

859. The above factors, taken together are likely to result in significantly reduced volumes of radioactive waste being generated (per unit of electricity generated) in the UK EPR^{TM}.

a) Evidence 129: Rooms, Systems and the Materials/Design for Decommissioning

860. A number of features have been incorporated into the UK EPR^{TM} design to minimise the creation, transportation and deposition of contamination and to minimise the contamination and/or activation of rooms, systems and materials. These design features can be grouped into several categories:

- The choice of materials specified in the design will limit the risk of activation and of corrosion, which in turn will minimise the waste produced and replacement of equipment, facilitating maintenance and decommissioning:
    - Wherever possible the materials selected will have a minimal propensity to become radioactive through activation, by avoiding in particular the use of materials containing high concentration levels of additives or impurities which are likely to generate gamma emitters and long-lived radionuclides after irradiation, (see Argument 4 for further information on selection of materials and components).
    - The use of porous materials is avoided in areas which can be contaminated as they are poorly suited to radioactive waste storage.
    - The use of non-inert materials, such as brick and plaster, whose presence in a significant quantity prohibits the use of the waste as fill, is avoided;
- The use of shielding and barriers which minimise the activation and contamination of equipment in normal and accident conditions.
- Design of access points in nuclear areas, handling equipment and access routes, and use of equipment which is easy to disassemble and protective devices which are easy to clean, with the objective of reducing the expected duration of exposure of workers to radioactivity and contamination.
- The use of activity monitors for contamination and dosimetry measurements, in order to reduce exposure to workers by limiting time to within operator dose parameters.
- Ensuring complete design, construction and decommissioning plans are available that give an accurate inventory and location of the radioactive materials and other hazardous materials throughout the plant lifecycle including for the end of reactor operation.
- Ensuring the design takes into account parameters to enable ease of maintenance and decommissioning of the facility.

861. The current UK EPR^{TM} reactor dismantling waste management strategy for high activity items such as the heavy reflector, lower support plate, hold down spring and bolting pins and, under conservative estimates, the core barrel consists of size reduction and packaging into 3m^3 Boxes. Such items will arise at five years post End of Generation (EoG). However, a potential discrepancy has been identified in the assessment of the decommissioning waste inventory for reactor dismantling. As assessment was undertaken of the inventory against the High Level Waste (HLW)/ ILW interface of 2kW/m^3 and the waste was determined to be heat generating ILW.

862. The heat limit for ILW in a $3m^3$ Box limit for transport to the GDF is 400W. At EoG + 5 years, the heat load per Box is anticipated to be significantly higher than the limits for transport and disposal [Ref 148]. Therefore, an alternative waste management strategy is required.

863. The optioneering report [Ref 149] identifies the preferred waste management option and document the modifications required to the HHI ILW store to enable the selected waste management option. The optioneering report captures the outcomes from each stage of the optioneering process, along with underpinning reasons as to why these decisions were reached. The optioneering report [Ref 149] provides an account of each stage in the Optioneering process, referencing out to supporting documents, where appropriate, to provide further detail. The optioneering report concludes that decay storage using the Shielded $3m^3$ Box (Croft SAFSTORE) is the preferred option for storage of SZC Reactor Dismantling waste.

b) Evidence 130: Use of Shielding and Barriers

864. The reactor design includes neutron shielding. This shielding reduces the activation of materials and thereby facilitates the clean-up of the structures while reducing the volume of active waste. The principal reactor core shielding components are:

- The neutron shield (also referred to as 'heavy reflector') surrounding the core, made of a dozen circular elements joined together by vertical tie-rods; and,
- The slab positioned above the vessel, made of removable concrete plates.

865. This shielding is unavoidably activated during reactor operation to a significant degree but is designed to be dismantled in sections. This makes it possible to remove it once commercial operation of the reactor has ceased, while exposing workers to minimal dose. The installation of this shielding results in additional arisings of ILW in comparison with other reactor designs which do not incorporate a heavy reflector. However, the heavy reflector is also of benefit in extending the lifetime of the reactor vessel by reducing its irradiation by neutrons.

866. The reactor design facilitates access at minimal dose rates in nearly all of the controlled area. This is due to the fact that wherever possible, the active components have been enclosed in bunkers or isolated behind screens, for example:

- the floor separating the pressuriser spray function from the pressuriser pressure relief function;
- the walls separating the hot legs from the cold legs; and,
- the bunkers in which the most active valves are placed.

867. Furthermore, measures have been taken to facilitate access to equipment and to create protected working and emergency shutdown areas, for example, by:

- the strengthening of the biological shielding of the annular region;
- the implementation of shielding baffles in front of the reactor coolant pumps;
- the implementation of shielded doors in front of the SGs;
- the operating floor above the cavity (pool), permitting the installation of an in-situ dismantling workshop;
- the access areas introduced around the main components;
- shielding of the resin tanks, by increasing the shielding of walls and floors in some in the form of steel plate [Ref 150]; and,
- additional shielding (steel plate or concrete) of glove boxes.

868. All of these measures help to reduce exposure level and time of staff undertaking manual operations and they also facilitate the use of remote controlled equipment.

c) Evidence 131: Design for Ease of Maintenance/Decommissioning

869. In terms of the approach to aid decommissioning, the design will draw on international experience from previous decommissioning activities as well as the studies under way and the initial feedback from significant decommissioning projects in France and worldwide.

870. The experience gained in the replacement of large components when operating nuclear plants during shutdown for annual and ten-yearly outages of these facilities has identified the causes of high doses to maintenance staff. Except for those associated with the presence of a neutron flux or very short-lived radionuclides, most of the causes, and particularly those which extend the time spent by workers close to irradiated equipment elements, will apply during decommissioning. The design measures taken to facilitate maintenance will therefore have a positive effect on the decommissioning operations.

871. A key aspect of the design is also to minimise the potential areas that might come into contact with radioactivity, an example of this being that when designing process plant circuits there is a requirement to minimise lengths of connecting pipe-work.

872. Decontamination of systems and components prior to their dismantling is an effective and widely accepted method of reducing the volume of radioactive waste. The design has therefore, as far as possible:

- taken into account decontamination requirements by placing injection seals in such a way as to maximise the wetting of the internal surfaces, and by including drainage lines and tanks, and sampling points;
- provided for the protection, if required, of floors and walls with surface coatings, which can be decontaminated or removed;
- provided for the coating or lining of the walls of submerged enclosures; and,
- on a case by case basis, provided for the treatment of metal surfaces to avoid the deposition of contamination and facilitate the removal of contaminated deposits.

873. The presence of a metal liner on the internal wall of the reactor building greatly eases the clean-up operations and the subsequent demolition of the HR. The concrete will be protected against any contamination and will be reusable by design; the liner will be cleaned and then declassified.

874. With respect to the fuel pools they have a:

- watertight liner made of metal panels of austenitic stainless steel sheets free of molybdenum with characteristics described in the ETC-C; with a,
- minimum thickness of 4 mm for the vertical sheets and 6 mm for the bottom of the pools.

This structure has been designed with the following requirements in mind:

- The liner must be water-tight, able to be decontaminated, and must resist corrosion and irradiation;
- the requirements for leak resistance of the liner must fulfil the various load assumptions defined in the ETC-C;
- equipment located in the pools is fixed to plates anchored directly to the structural concrete wall in order to avoid the transmission of stresses to the liner; and,
- any leak must be detected, the leakage collected, and the leak repaired.

6.3.2 Claim 3, Argument 17: Selection of Methods to Minimise Solid Waste Generation

875. The use of low-waste technology is one of the four key principles described in Chapter 8 of the GDA PCER [Ref 47] developed to support the GDA. An important aspect of this is the selection of methods and materials which minimise the generation of solid waste. The minimisation of operational wastes and facilitation of decommissioning to minimise the volume of waste for disposal to other premises is dealt with in Argument 15.

876. Solid radioactive wastes are generated during operation of the UK EPR^{TM} as a result of the application of abatement techniques to liquid and gaseous waste arisings. This argument is concerned with the selection of the methods or materials to minimise the generation of solid wastes arising from the use of the techniques to abate liquid and gaseous discharges.

877. The main factors associated with selection of methods and materials to minimise the volume of solid wastes associated with the application of abatement techniques to liquid and gaseous discharges are discussed below:

- Minimisation of solid wastes arising from the abatement of gaseous effluents [Evidence 130]:
    - Use of pre-filters. The use of coarser pre-filters contributes to longer downstream HEPA filter life by ensuring that the filters are not blinded with larger sized particulates.
    - The configuration of filters for the removal of particulates and aerosols from gaseous effluents. These are selected on the basis of efficiency of particulate removal, thereby ensuring that the minimum volume of waste is generated for the treatment of gaseous effluents required. The volume of waste HEPA filters is also minimised by ensuring that filters are changed based on differential pressure drop. They are replaced when performance drops (i.e. before they are blinded), as opposed to changing on the basis of pre-defined frequency. The conditioning of air in terms of drying also contributes to extending the service-life of filters. The use of HEPA filtration is recognised to be international best practice in the nuclear industry worldwide and is considered to be BAT [Sub Argument 24].
    - Specification of Inlet Filters. These filters remove atmospheric dust from air drawn into the designated areas which extends the service life of the extract filters. [Evidence 114].
    - Spent activated charcoal arising from the removal of short-lived isotopes from gaseous effluents. Activated charcoal delay beds are used to abate short-lived isotopes (noble gases and halogens) from gaseous effluents. The activated charcoal is designed for a plant life of 60 years. This minimises the volume of solid waste associated with removal of short-lived isotopes as the delay beds are not expected to be replaced during the operating life of SZC [Evidence 108].
- Minimisation of solid wastes arising from the filtration of liquid effluents [Evidence 131]. Filters for liquid effluents are selected on the basis of efficiency of removal of particulate material which ensures that the minimum volume of waste is generated for the treatment of liquid effluents. Single use cartridge filters will be changed on the basis of differential pressure drop or when a pre-defined radioactivity level limit has been reached. This will minimise waste arisings whilst also reducing radiation doses to workers undertaking filter changes. Pre-filters and strainers of large pore size will be used to maximise the operational life of filters of smaller pore size.
- Minimisation of solid wastes arising from the demineralisation of primary coolant and spent liquid effluents [Evidence 132]. Ion exchange resins arise from the demineralisation of primary coolant and effluents arising from treatment processes for the secondary circuit, including the APG. The use of ion exchange resins for demineralisation is standard practice in PWRs worldwide. Resins are

selected on the basis of the efficiency of removal of soluble species from liquids (known as capacity) and are specified to be "nuclear" grade to meet the quality requirements of the relevant systems in which they are used. This contributes to the minimisation of solid waste arisings associated with spent resins by maximising the efficiency of removal of ionic species and maximising resin bed lifetimes. The selection of three different types of resins to optimise removal of ions from the effluents, namely strong high-capacity anionic resins; strong high-capacity gel-type cationic resins; and mixed-bed-type also contribute to minimising arisings of resins by maximising the efficiency of removal. A key aspect of the use of ion exchange resins for demineralisation is the ongoing optimisation of performance during operation, based on review of operational experience and international practice [Evidence 93].

- Minimisation of solid wastes arising from the evaporation of primary coolant and non-recycled effluents [Evidence 133]. Evaporator concentrates arise from evaporation of primary coolant and non-recycled effluents. Implementing an evaporation stage in the treatment of effluent from nuclear power stations enables the minimisation of the generation of radioactive wastes from the facility by concentrating the activity into the concentrate. These concentrates, which contain the majority of the radioactivity, are typically converted into a solid form prior to disposal. This approach both minimises the activity of waste discharged to air or water and reduces the volume of solid wastes requiring disposal.

a) Evidence 132: Minimisation of solid wastes arising from the abatement of gaseous effluents

878. There are a number of elements to filtration systems that contribute to the minimisation of solid waste arisings as well as to filtration performance. This is primarily achieved by reducing the frequency by which filters are changed and therefore minimising the volume of solid waste generated from such operations.

i. Air inlet pre-filters

879. The filters used at air inlets are used to filter atmospheric dust. These filters normally have a relatively low efficiency but a higher efficiency filter may be used depending on site specific conditions such as high dust loadings in air due to an industrial or agricultural environment.

ii. Extraction pre-filters

880. The pre-filters used for extraction, upstream of the HEPA filters, are designed to lengthen the service life of HEPA filters by filtering large particles from the air flow.

iii. Activated charcoal

881. The activated charcoal is designed for a plant life of 60 years. This minimises the volume of solid waste associated with removal of short-lived isotopes

b) Evidence 133: Minimisation of solid wastes arising from the filtration of liquid effluents

882. The generation of ILW filters is determined by the specific activity and particulate burden of the primary coolant and other systems. The amount of fission and activation products presents in liquid effluents, as well as the chemical conditions within the reactor influence the amount of resin required to remove activity from liquid effluents. Therefore, the generation of liquid filter cartridges and spent resins will be minimised by the application of existing good practice relating to the minimisation of particulate material and the build-up of corrosion products in primary coolant [Arguments 4 and 5].

883. The use of single-use cartridge filter technology has for some time been the preferred technique for particulate removal in primary coolant and radioactive liquid effluent systems for all PWRs. Different types, brands and

specification of cartridge filters can be used, depending on the characteristics of the liquid to be treated. There is considerable experience in the use of cartridge filtration for PWR liquid effluent treatment and the management of spent filters [Ref 5].

884. The characterisation of the radioactivity in the filters (i.e. a spectrum will be created) will be carried out so as to determine the speciation of the radionuclides present, instead of a simple gamma count.

885. This will allow a better analysis of whether the filter needs changing or not, especially if short half-life radionuclides are being trapped. This will mean that filters will be changed less and hence further optimisation of the filter usage.

c) Evidence 134: Minimisation of solid wastes arising from the demineralisation of primary coolant and spent liquid effluents

886. The demineralising operations involve passing the effluent through resin beds that fix the elements present in ionic form in the effluent. This technique is in particular used for the treatment of radioactive effluent to remove very low levels of contamination, but also for the production of demineralised water. The life of a demineralisation unit is however considerably reduced by chemical pollution.

887. The amount of fission and activation products in the primary coolant, as well as the chemical conditions within the reactor influence the amount of resin required to remove activity from liquid effluents. Therefore, the generation of spent resins will be minimised by the application of existing good practice relating to the minimisation of fission and activated corrosion products in primary coolant [Arguments 4 and 5].

888. Ion exchange resin based equipment has been incorporated into the UK EPR^{TM} liquid effluent treatment plant design. When choosing the ion exchange resins, the UK EPR^{TM} design has ensured that a number of requirements will be met for the minimisation of the volume of waste disposed to other premises.

889. The following will dictate the selection of an optimised ion exchange resin:

- Optimisation of formulation of mixed beds: proportion of cation/anion exchange resins (reduction in “hold-up” of enriched boron on the anions, better trapping of corrosion products and recycling of lithium).
- Recommended use of ion exchange resins whose:
    - Total capacity and rated capacity are as high as possible (long-life and effectiveness).
    - Macroporosity and crosslink density of polymers making up the ion exchange resins are better defined to make the resin loads more effective and longer-lasting [Ref 151].

890. Segregation of liquid effluent according to their chemical and radiochemical characteristics [Sub Argument 19] allows use of demineralisation where required only. Therefore, resin beds are used for specific types of effluents. In combination with the factors listed above, this will ensure that demineralisers are used only on those effluent streams that are compatible with the ion exchange resins and where demineralisation as a treatment is beneficial. This results in minimisation of spent resin arising from liquid waste treatment.

891. Certain resin beds may be designed to be operated to exhaustion, regardless of the radioactivity that they accumulate. The continual use of the demineraliser until it becomes spent ILW may represent best practice for minimising spent resin arisings for these treatment processes where activity levels are most significant. Process monitoring enables operational decisions on when to change resin to be optimised.

d) Evidence 135: Minimisation of solid wastes arising from the evaporation of primary coolant and non-recycled effluents

892. Evaporation is carried out on effluent from the chemical drains after they have been coarse filtered. Similarly, to the primary effluents, the evaporator (distinct to that used for primary coolant in the TEP) separates the spent effluents into distillates (only weakly active and/or chemically polluted) and concentrates (containing most of the activity and soluble and particulate chemical components). The distillates are subsequently sent either to a discharge tank or back to the evaporation system for additional treatment, and the concentrates, to the TES. Process and floor drains can also sometimes be treated by evaporation.

893. The treatment of the evaporator concentrates and sludges was considered in an optioneering report [Ref 152], in order to identify the BAT and ALARP options. It was identified that the BAT option is the encapsulation of concentrates and sludges in a cementitious matrix using on-site retractable equipment similar to that used on French 900 MWe plants.

6.3.3 Claim 3, Argument 18: Application of Volume Reduction Processes to Solid Wastes

894. For those solid radioactive wastes that cannot be prevented and have been minimised as far as practicable, the volume of solid radioactive waste that is disposed of will be reduced for the following reasons:

- To make the most effective use of the waste management infrastructure.
- To minimise the quantity of secondary wastes associated with waste management practices.
- To reduce pressure on existing and future disposal facilities.

895. The specification of the solid waste management facility is still under development. However, the following techniques are expected to be considered:

- Low Force Compaction. On-site compaction is a relatively basic but effective volume reduction technology which is in use in the UK at the current time. The optimum method of compaction is with a mixture of materials such as metal which will permanently deform trapping materials such as plastics in the voids. Compaction does not produce any secondary solid wastes and any dust created is contained using a suction hood and contained within the Effluent Treatment Building. Compaction is addressed in the EARWG best practice guidance which states that volume reduction factors for compaction are typically between 3 and 10 [Evidence 135].
- High Force Compaction. Shipping the waste from its site of origin for high-force compaction has been suggested for liquid effluent filters. High force compaction reduces the volume of waste to a higher degree prior to disposal. Although high force compaction is likely to take place off-site and does not contribute to the claim that waste transferred to other sites will be minimised, it is recognised as the best practice for specified wastes and will reduce the volume that is ultimately disposed of [Evidence 136].
- Diversified Disposal Routes. Wherever possible, the volume of waste disposed of from SZC to the LLWR will be minimised by utilising alternative disposal options. For instance, the resins (from SG blowdown ion exchangers, likely to be VLLW) resulting from treatment of blowdown system effluent via disposal to suitably permitted landfill sites. Utilising alternative disposal routes has the benefit of avoiding the containerisation and conditioning requirements for the LLWR which increase the volume of waste ultimately disposed of. Greater application of Clearance and Exemption working group code of practice principles is expected to increase quantities of waste cleared and exempted with corresponding environmental, cost and LLWR capacity preservation benefits [Ref 148]. This supports the high importance placed on sound characterisation of each of the waste routes proposed by SZC Co. for SZC where waste could be diverted away from the LLWR

[Evidence 137].

- Incineration. Incineration will take place off-site. The majority of the radioactivity will be captured in the ash which will be disposed of as solid waste. There are aerial emissions associated with incineration. However, any particulate will be sampled, monitored and abated using HEPA filtration. The HEPA filters will require disposal. The solid waste produced (ash and filters) will be much less than the original volume of waste put into the incinerator. Thermal treatments are addressed in the EARWG best practice guidance which states that these are extremely effective volume reduction techniques for combustible materials. Incineration can give a high volume reduction (up to 100:1) by chemically destroying the organic constituent of the waste. As with high force compaction, incineration which takes place off-site and although it does not contribute to minimisation of waste transferred to other premises it provides a means significantly reducing the volume of waste ultimately requiring disposal. Incineration also provides a very effective route for the disposal of specific waste streams, such as oils, where the alternatives (e.g. encapsulation) result in the generation of large volumes of solid waste [Evidence 138].

896. Volume reduction is an effective, mature and relatively low-technology method of reducing the volume of solid waste that will require disposal. The proposed techniques are expected to improve the efficiency of waste routes and promote the availability of disposal facilities. In particular, when waste is disposed to LLWR it will be assured that the waste is compacted as much as practical for waste type to preserve LLWR capacity.

a) Evidence 136: Design of waste management facilities to minimise solid waste arisings

897. Firstly, disposal points for non-radioactive wastes will be provided outside radiation controlled areas to prevent unnecessary waste from entering the areas and becoming contaminated. Secondly, waste disposal facilities, inside and outside of radiation controlled areas, will be zoned to enable the most effective segregation of the waste. This will include the segregation of clean waste from radioactive waste and those wastes which are destined to undergo different forms of treatment. This is one of the most effective methods of volume reduction and has the added advantage of segregating any items which may have hazardous properties and require different disposal route (i.e. aerosols in LLW which is destined for the LLWR).

898. At the design stage the volume of solid radioactive waste arisings from the UK EPR^{TM} are reduced by minimising waste arisings at source and segregating waste. This includes designation at the design stage of clean-waste zoning, enabling a better sorting of waste at source and the segregation of conventional waste from non-contaminating work in the restricted area.

b) Evidence 137: Use of compaction to minimise solid waste volume

899. The TES conditions the low level activity and very low level activity waste. The LLW is first conditioned in airtight vinyl sacks and stored temporarily in the HN or the Effluent Treatment Building. It is then sorted, ground or compacted then conditioned in metal or 200 L PEHD (high-density polyethylene) drums. Compacting is performed in the Effluent Treatment Building.

900. The press used for compacting is equipped with a suction hood to prevent the spreading of dust and a shield placed in the drum to prevent its deformation.

901. This excerpt from the EARWG best practice guidance explains why compaction is an effective volume reduction method.

> *"Compaction is a widely used method to reduce the volume of dry radioactive waste through the application of mechanical force. There are a variety of compaction devices available on the market specially designed for use with radioactive waste. Many commercially available processes designed for use with general rubbish can be modified for use with radioactive waste (such as adding containment and ventilation). Volume reduction factors for compaction vary according to the compaction force and the feed*

> *material but are typically between 3 and 10 and up to 25 for super compaction. Compaction reduces the waste volume by reducing the amount of voidage in the waste"* [Ref 106].

c) Evidence 138: Use of high force compaction to minimise solid waste volume

902. The Integrated Waste Strategy for SZC provides more evidence for waste volume reduction techniques which are to be applied to wastes such as Dry Active Waste and active effluent filters. EARWG reports a volume reduction factor of up to 25 for super compaction [Ref 106].

d) Evidence 139: Use of diversified waste routes

903. Changes in Government policy has led to changes in the management, disposal and regulation of solid LLW in the UK. The changes are likely to facilitate the disposal of VLLW to permitted landfill rather than transfer for disposal of VLLW to the LLWR. Due to the need to preserve capacity at the LLWR, disposal of VLLW to it is considered to be unsustainable and the least preferable option given other alternatives are available.

904. Wherever possible, disposal from SZC to the LLWR will be avoided by utilising alternative disposal options. For instance, the resins (from SG blowdown ion exchangers) resulting from treatment of blowdown system effluent are expected to be VLLW. The following quote is taken from the SZC Integrated Waste Strategy:

> *"The strategy for the low activity resins is disposal by means of controlled burial to landfill as VLLW when, or if, this disposal route becomes available. If such a route is not available then SZC Co. will explore alternative disposal routes such as incineration and will only dispose of this waste to the LLWR, where acceptance for disposal has been agreed in principle, unless we can demonstrate this is the best option. Methods to minimise the volume of waste disposed of to the LLWR would be adopted, such as mixing with other wastes with greater voidage (pipes, rubbles etc.). This strategy is consistent with the national strategy for LLW and will utilise alternative disposal routes to the LLWR if and when they become available. This will contribute to the minimisation of disposal of wastes to the LLWR and thus to maximising its remaining operational lifetime.*

e) Evidence 140: Use of incineration and thermal treatment for solid waste disposal

905. Suitable solid radioactive wastes arising from the operation of the UK EPR^{TM} will be incinerated.

906. The following excerpt from the EARWG best practice guidance explains why incineration is an effective volume reduction method.

> *'Thermal treatment processes include a wide variety of oxidative and pyrolytic technologies. These are extremely effective volume reduction techniques for combustible materials. Incineration is the most common thermal waste treatment*.
>
> *The following waste streams can generally be treated by incineration depending on the incinerator concept employed:*
>
> - *dry solid wastes;*
> - *ion exchange resins;*
> - *organic liquids; and,*
> - *aqueous liquids.*
>
> *The processes give a high reduction in mass (up to 10:1) and a high volume reduction (up to 100:1) by chemically destroying the organic constituent of the waste* [Ref 106].'

907. In their 'Integrated Waste Management – overview', the Nuclear Decommissioning Authority (NDA) has identified learning from its sites Integrated Waste Strategies. The NDA has identified an opportunity to make

more use of waste incineration which is currently used in the UK by existing nuclear facilities as a method of volume reduction [Ref 153].

908. The main advantages of using incineration as a technique for treating combustible waste (once the waste is determined to be suitable for incineration) includes the significant volumetric reduction in the waste form which facilitates the increase in allocation capacity for more efficient use of volumetric and radiological capacity at the LLWR which is a national resource. Additionally, the option of incineration reduces the use of clean material for disposal (e.g. grout) and other resources that would have been used in the management, handling and long-term storage of the waste. The ash produced by incineration is also a more stable waste form and unlike the pre-treated waste, will not generate a secondary gaseous waste through biodegradation.

6.3.4 Claim 3, Argument 19: Selection of the optimal disposal routes for wastes transferred to other premises

909. The disposal of the waste from SZC will depend on the radioactivity level and physical characteristics of the waste produced. A number of treatment and disposal routes are anticipated to be available for LLW waste generated by SZC requiring transfer to other premises (Evidence 137).

910. ILW generated at SZC will be disposed of to the national GDF when it is available (2040 at the earliest) [Ref 8]. Until that time, ILW will be stored on site in the HHI; the method of storage (i.e. encapsulation) must be demonstrated to be compatible with the requirement conditions of the GDF. Radioactive Waste Management Ltd. (RWM) manage the disposability assessments for this process (Evidence 140) that SZC complies with through design of appropriate ILW interim storage technology and infrastructure.

a) Evidence 141: Selection of preferred disposal option

911. For the disposal of LLW, a key consideration of the choice of preferred disposal route has been the commitment to demonstrate best use of existing UK LLW management assets. Therefore, direct disposal to LLWR is seen as the least desirable option and where a reasonably practicable alternative disposal route exists, e.g. incineration or metal melting, this has been chosen as the preferred option. This approach is consistent with the national strategy for LLW and SZC Co. will aim to utilise alternative disposal routes to the LLWR when available and demonstrated as being the BAT. This will contribute to the minimisation of disposal to the LLWR and maximise its remaining operational lifetime.

912. The strategy for LLW is that waste generated throughout nuclear power plant operations and decommissioning will be disposed of as soon as reasonably practicable, following treatment to minimise volume and perform appropriate conditioning or packaging. The ultimate disposal of the wastes is expected to be via one of the following main routes depending on the radioactivity level of the waste produced, its physical characteristics and its chemical properties:

- Recycling of metals via commercially available routes.
- Incineration of combustible wastes using commercially available routes.
- Disposal to facilities authorised to accept exempt waste (notably for soil, rubble and aggregates) where no reuse or recycling options are viable.
- Disposal of LLW at LLWR where the above alternatives are not viable.

913. The SZC Integrated Waste Strategy [Ref 8] provides further detail on the off-site facilities identified for potential disposal of LLW from SZC.

914. In support of the RSR permit application process a Disposability in Principle has been received from LLWR for disposal/ treatment of waste from the UK EPR^{TM} via the above routes using the LLWR framework of services [Ref 156]. SZC Co. will in due course develop appropriate commercial arrangements with waste service provider(s).

915. Rod Cluster Control Assemblies; Thimble Plug Assemblies; Primary (neutron) Source Assemblies; and Secondary (neutron) Source Assemblies are anticipated to be in part ILW. They will be stored with spent fuel. This approach justified for HPC by [Ref 154], is equally applicable to SZC. Importantly co-storage minimises storage and waste management requirements and does not foreclose final disposal options.

916. There is potential that some in core instrumentation, such as Self Powered Neutron Detectors, which are anticipated to be in part HLW at the point of generation to require moving from their reference storage location before the end of generation. Feasible options have been identified for their management should this scenario arise and work is ongoing for HPC to identify the BAT/ALARP preferred option. The SZC project will replicate the finalised approach for the management from HPC.

b) Evidence 142: disposability assessments

917. Before conditioning and packaging of ILW that is not anticipated to decay (Ion Exchange resin and Filters), regulatory arrangements require that sites produce an ILW conditioning proposal. This will include a demonstration that, following conditioning, the waste will be compatible with existing or future planned management and disposal options. This requires that a LoC is obtained for the packaging proposal. The LoC process is the mechanism that RWM utilises to provide confidence that a waste package can be accepted at a future GDF.

918. The overall objective of the LoC assessment process is to give confidence to all stakeholders that the future management of waste packages has been taken into account as an integral part of their development and manufacture. This is achieved by the site operator working with RWM to demonstrate that the waste packages produced by a proposed packaging process and their subsequent storage will be compliant with the generic waste package specification and compatible with plans for transportation and emplacement in the planned GDF.

919. In cases where the assessment has concluded that the waste package is compliant with the GDF and is sufficiently underpinned, RWM is prepared to confirm this by the issue of a LoC.

920. During the UK EPR^{TM} GDA, RWM carried out a disposability assessment of the High Activity Waste and spent fuel anticipated to be generated by a UK EPR. This assessment, which included decommissioning waste, concluded that, “compared with legacy wastes and existing spent fuel, no new issues arise that challenge the fundamental disposability of the wastes and spent fuel expected to arise from operation of such a reactor. This conclusion is supported by the similarity of the wastes to those expected to arise from the existing PWR at Sizewell B. Given a disposal site with suitable characteristics, the wastes and spent fuel from the EPR^{TM} are expected to be disposable.” [Ref 155]. In addition, since GDA RWM Ltd have provided further confidence that operational ILW anticipated to be generated by the HPC and SZC Power Stations will be disposable by issuing a conceptual LoC [Ref 156]. The SZC project will engage with LLWR and RWM Ltd to ensure a level of confidence appropriate to the project phase is achieved for the disposability of anticipated waste and spent fuel. Wherever possible the SZC project will look to benefit from disposability assessments carried out for the HPC project.

6.4 Claim 4: SZC Co. Shall Minimise the Impacts on the Environment and Members of the Public from Radioactive Waste that is Discharged or Disposed of to the Environment

921. The design of the UK EPR^{TM} has focussed on reducing the amount of radioactivity that will be disposed into the environment surrounding the site on which it is located. Where discharges of radioactivity to air and water are unavoidable, techniques have been adopted to ensure that the subsequent impacts to the environment and human population are ALARA. The approach adopted fulfils the requirement of:

- Condition 2.3.2(c) of the proposed standard template of the RSR environmental permit [Ref 20] states that:

> *’The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public’*

922. The approach also demonstrates that the following Environmental Principle has been taken into account during this stage of the programme:

- Principle RSMDP7 of the RSR - Environmental Principles [Ref 21] – BAT to Minimise Environmental Risk and Impact.

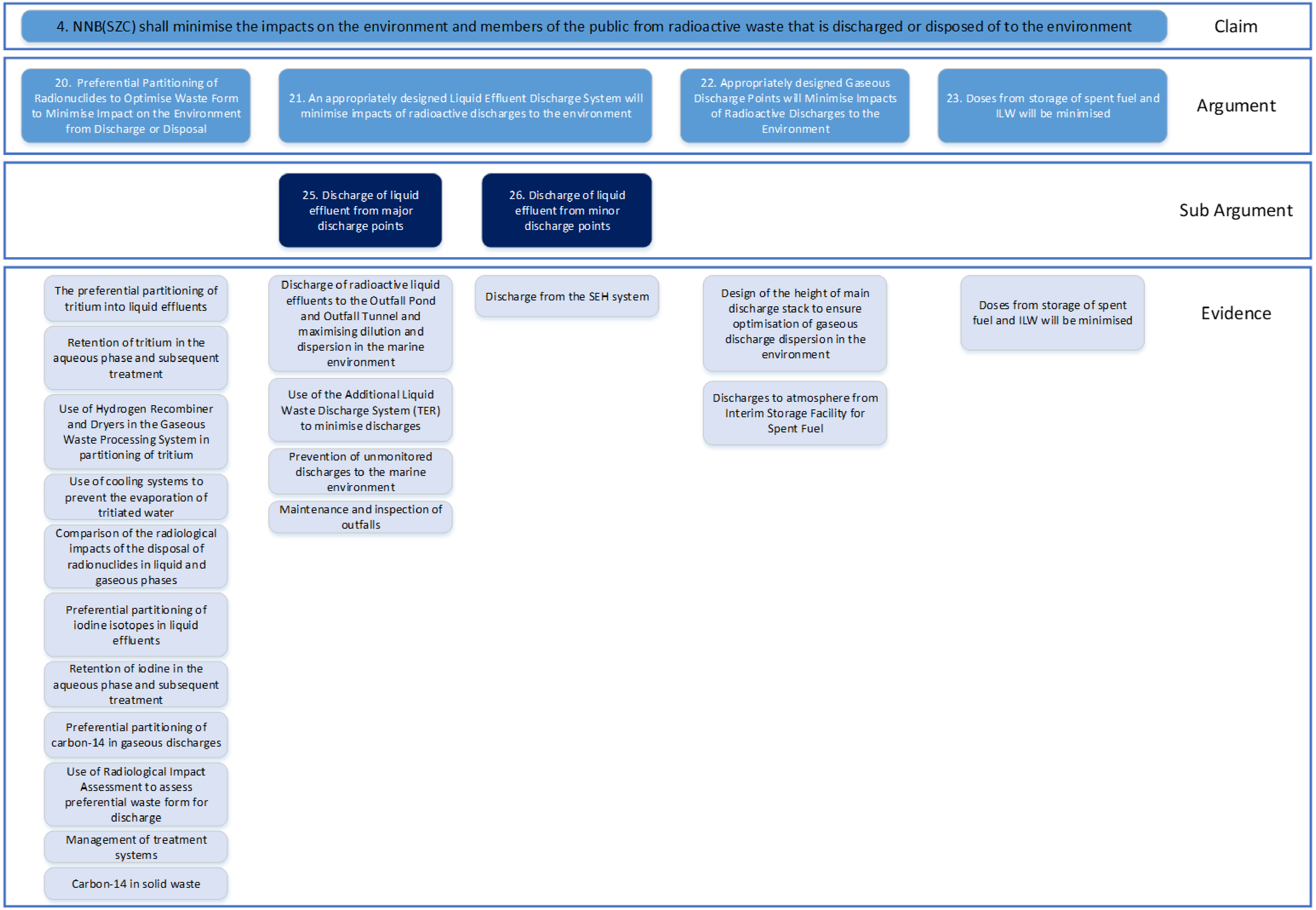
923. The design of the power station proposed for SZC contains a range of features that contribute to substantiating this claim. These features are presented in the arguments that follow this claim. Those that are considered particularly important at this stage of the programme are:

- partitioning of radioactive substances to ensure specific nuclides are contained or discharged in an optimised manner (i.e. the distribution of radionuclides between liquid, and gaseous wastes) depending on their potential radiological impacts and their physical and chemical properties; and,
- minimising the impacts of discharges to the marine and atmospheric environments by means of design and operation of the discharge outlets.

924. Taken together, the proposed features are expected to ensure that any unavoidable discharges of radioactive waste to air or water result in radiological effects to the environment and members of the public that are ALARA.

925. Impacts on the environment and members of the public will also be minimised by ensuring that the spent fuel from SZC will be suitable for future disposal in a deep geological repository should this option be required in the future.

926. Figure 6-11 shows the structure of the Claim, Arguments, Sub Arguments and Evidence.



Claim

4. NNB(SZC) shall minimise the impacts on the environment and members of the public from radioactive waste that is discharged or disposed of to the environment

Argument

20. Preferential Partitioning of Radionuclides to Optimise Waste Form to Minimise Impact on the Environment from Discharge or Disposal

21. An appropriately designed Liquid Effluent Discharge System will minimise impacts of radioactive discharges to the environment

22. Appropriately designed Gaseous Discharge Points will Minimise Impacts of Radioactive Discharges to the Environment

23. Doses from storage of spent fuel and ILW will be minimised

Sub Argument

25. Discharge of liquid effluent from major discharge points

26. Discharge of liquid effluent from minor discharge points

Evidence

The preferential partitioning of tritium into liquid effluents

Retention of tritium in the aqueous phase and subsequent treatment

Use of Hydrogen Recombiner and Dryers in the Gaseous Waste Processing System in partitioning of tritium

Use of cooling systems to prevent the evaporation of tritiated water

Comparison of the radiological impacts of the disposal of radionuclides in liquid and gaseous phases

Preferential partitioning of iodine isotopes in liquid effluents

Retention of iodine in the aqueous phase and subsequent treatment

Preferential partitioning of carbon-14 in gaseous discharges

Use of Radiological Impact Assessment to assess preferential waste form for discharge

Management of treatment systems

Carbon-14 in solid waste

Discharge of radioactive liquid effluents to the Outfall Pond and Outfall Tunnel and maximising dilution and dispersion in the marine environment

Use of the Additional Liquid Waste Discharge System (TER) to minimise discharges

Prevention of unmonitored discharges to the marine environment

Maintenance and inspection of outfalls

Discharge from the SEH system

Design of the height of main discharge stack to ensure optimisation of gaseous discharge dispersion in the environment

Discharges to atmosphere from Interim Storage Facility for Spent Fuel

Doses from storage of spent fuel and ILW will be minimised

Figure 6-11 Claim 4 Structure

6.4.1 Claim 4, Argument 20: Preferential Partitioning of Radionuclides to Optimise Waste Form to Minimise Impact on the Environment from Discharge

927. The partitioning (distribution) of radioactive substances between liquid, gaseous or solid wastes to minimise environmental impacts is a feature of the PWR design and a function of the chemical and physical processes involved in their production. The partitioning of the most radiologically significant radionuclides arising in the UK EPR^{TM} primary coolant between the gaseous and liquid phases enables the discharge/ of wastes in the optimum waste forms (i.e. in liquid, gaseous or solid wastes). This minimises the radiological impacts of the discharge/ of radioactive waste arisings from SZC.

928. It should be noted that the purposeful partitioning of radionuclides from liquid and gaseous effluents into solid wastes is essentially addressed by the use of abatement techniques such as filtration, ion exchange and demineralisation, and as such is not covered under this argument. The partitioning of activity into solid wastes, as required by the conditions of the RSR environmental permit is described in Claim 2. The partitioning of radionuclides from liquid and gaseous effluents and solid wastes maximises the potential to concentrate and contain radioactivity in solid wastes through the application of appropriate abatement techniques. The abatement of discharges of noble gases by means of the use of charcoal delay beds is dealt with in Evidence 108. This argument focuses on the partitioning of radionuclides between liquid and gaseous wastes to minimise the radiological impacts of their discharge.

929. This partitioning is common to all PWR designs. In addition, some UK EPR^{TM} design features, such as sharing tank ullage and the use of catalytic recombination units for the removal of hydrogen and oxygen from the primary circuit, are beneficial with respect to the partitioning of a number of radionuclides between the liquid and gaseous phases. All of the aspects of the UK EPR^{TM} design which promote radionuclide partitioning are advantageous features for radioactive waste management. In some cases, there is little or no control over partitioning, for instance the release of noble gases to atmosphere. However, where radioactive emissions can be controlled by means of partitioning, the preferred route is defined and will be used.

930. The key aspects of the partitioning of radionuclides which minimise the impact of their discharge into the environment are:

- The preferential partitioning of tritium into liquid effluents [Evidence 143].
- The preferential partitioning of iodine isotopes into liquid effluents [Evidence 146].
- The preferential partitioning of carbon-14 into gaseous discharges [Evidence 148].

931. A number of the vented liquid effluent process tanks of the UK EPR^{TM} radioactive liquid effluent treatment system (TEU), and the TER are designed to be shared and thus will be included in the design for SZC. Gaseous discharges from tanks are lowered by reducing the contact area for the partitioning of radionuclides through tank degassing or venting. The contents of a tank will have a given vapour pressure, which is proportional to both the surface area of the liquid effluent and also the available volume above the liquid interface. By reducing the available head space, or ullage, the volume above the liquid effluent is reduced, and consequently will reduce the amount of radioactivity which undergoes partitioning into the gaseous phase.

932. The preferential partitioning of radionuclides which arise as a result of the operation of the UK EPR^{TM} will minimise the radiological impacts of discharge/ of radionuclides in liquid and gaseous discharges from SZC. A wide range of international operational experience and nuclear industry standard practice pertaining to the partitioning of radionuclides has been considered. All of these data are fully relevant to the design and operation of SZC and considered to be BAT, based on the EA's guidance on Assessment of BAT [Ref 9].

a) Evidence 143: The preferential partitioning of tritium into liquid effluents

933. There are no cost effective methods for abatement of tritiated water vapour and the BAT option established at all PWR's is to discharge via the stacks serving the various areas where tritiated water vapour arises.

934. Preferential partitioning of tritium into liquid effluents minimises the radiological impacts of discharge into the environment. It is not practicable to minimise tritium arisings for liquid or gaseous discharges by partitioning to solid waste through abatement. The dose per unit discharge is higher for gaseous discharge of tritium than those for liquid discharges. The radiological impacts from tritium discharges are therefore lower when discharged as a liquid rather than a gas, which is reflected in the dose assessments for SZC and described in the GDA PCER Chapter 8 [Ref 47]. Discharges of tritium in gaseous effluents are low and minimised at source by the fuel cladding, and due to their chemical form remain in liquid effluents arising from primary coolant management.

935. Primary gaseous effluent is processed in the TEG. The recombination unit may help to ensure that tritium in the purge gas in the TEG is returned to and retained in the liquid phase, although to date this effect has not been quantified. It is considered unlikely that these parameters will be monitored directly at other EPR^{TM}'s, however OEF on discharges from other operational EPR^{TM}'s will be reviewed where available to assess these assumptions against actual data. As the primary function of the recombiner is for nuclear safety, the potential for preferential partitioning is considered a secondary benefit and it will not be possible to fine tune it's performance with regards to the environment.

936. The liquid effluent is collected in the RPE for either recycling in the TEP or discharge from the TEP for processing in the TEU prior to discharge.

937. Although the proposed annual maximum discharge value for liquid tritium can be considered to be significant (in terms of activity discharged), quantification of the impacts of these discharges on the dose received by members of the public is relatively low (see supporting document D1).

938. The doses for the gaseous and liquid discharges associated with the release of tritium, taken from the SZC RSR Permit Application Support Document D [Ref 10], show that the dose to the most exposed members of the critical groups from discharges from SZC are 0.16µSv/y. Given the size of the discharges, 6TBq/y for gases and 200TBq/y for liquids this illustrates that discharges of tritium have a low impact and that discharge into the marine environment is preferable to discharge to atmosphere.

b) Evidence 144: The Use of Hydrogen Recombiner and Dryers in the Gaseous Waste Processing System in partitioning of tritium

939. The UK EPR^{TM} design provides a significant reduction in discharges of gaseous radioactive waste, due to the design of the TEG. The main improvements which allow this are:

- Recombination of hydrogen in the off gas from tanks etc. into water. This also retains the majority of tritium and iodines in an aqueous phase.
- The recombination unit may help to ensure that tritium and iodines in the purge gas in the TEG are returned to and retained in the liquid phase, although to date this effect has not been quantified. The dominant isotopes remaining in the purge gas in the TEG are the shorter- lived noble gases (that also have lower environmental impacts).
- The recombiner unit is catalytic. The formation of water from hydrogen and oxygen begins at ambient temperature in the presence of a catalyst. The catalyst is designed for a plant life of 60 years. Therefore, the catalyst should perform efficiently over this time and will not need to be replaced during the operational phase of SZC. Not only does this control and minimise the discharge of gaseous activity, it also minimises the creation of a solid waste.
- The recombination unit seems to promote the dissolution of tritium and iodines. However, it cannot be confirmed as an improvement in terms of gaseous discharges since a number of points need to be clarified in terms of:

- physical and chemical impacts on the gaseous effluents other than hydrogen, in particular tritium, iodines, carbon-14 and potentially krypton;
- reliability of protective material and the downstream/outlet material; and,
- technology used; and,
- Monitoring provisions incorporated into the design to allow for sampling upstream and downstream of the recombiner unit, to allow quantification of its effect on tritium/carbon-14 speciation (see Evidence 170).

c) Evidence 145: Design to prevent the evaporation of tritiated water

940. The majority of discharges of tritium in gaseous effluent are as the result of evaporative losses from sources of tritiated water. Potential sources are:

- the IRWST (except the part of the tritium which recondenses on the cold parts of the EVR);
- the spent fuel storage pool; and,
- primary coolant effluent treatment systems.

941. Evaporative losses from the IRWST and the spent fuel storage pool are discharged to atmosphere through the stack after passing through the EBA [Ref 5].

942. To enable tritium to remain in the liquid phase, where it has a lower dose impact per unit discharged, the evaporation of tritium into gaseous form should be reduced as far is reasonably practicable. Evaporation of tritium in the spent fuel storage pool and the IRWST pool is mostly influenced by the temperature in the pools, in fact, the higher the temperature, the higher the evaporative losses of tritium. Evaporation of tritium can be reduced by the cooling systems that control the temperature of the IRWST, the reactor cavity during shutdown and the fuel pool liquid and gas blanket [Ref 5].

943. The spent fuel storage pool in the Fuel Building is cooled by the PTR that maintains the pool temperature within a range of admissible temperatures in normal plant conditions. The PTR is equipped with three cooling trains with one exchanger cooled by the Component Cooling Water System (RRI) for each train. It features the following optimisations:

- Optimisation of the size of the exchangers. The size of the exchangers has been optimised with respect to the cooling capacities (and needs), buildings/rooms’ size and overall dimensions, to ensure an optimal temperature in the pool is maintained (taking account of evaporation as well as other operational factors).
- Increased RRI flow rate through the PTR heat exchanger(s) when required during specific operational phases, where the other systems served by the RRI are less demanding or not in operation (e.g. refuelling outage).
- Simultaneous use of two the three PTR cooling trains during refuelling outages or operating conditions where high residual power has to be evacuated (e.g. due to the presence of fuel in the pool following unloading of the core for refuelling).

944. In addition to the pool temperature, the evaporation rate in the spent fuel storage pool is also dependent, although to a much lesser extent, on the ambient conditions in the Fuel Building. The evaporation rate decreases when the temperature and relative humidity in the Fuel Building increase. However, high ambient temperature and relative humidity present issues to workers and operation of equipment (in particular filtration equipment such as iodine filters). In addition, the ventilation systems that control the ambient conditions must also maintain a sub-pressure to contain radioactive substances.

945. Therefore, the evaporative losses of tritium from the spent fuel storage pool are optimised and represent a compromise between the containment of radioactive substances, working & equipment operating conditions and minimisation of the evaporation rate.

946. To reduce evaporative losses, the IRWST pool temperature is cooled by the Low Head Safety Injection pumps of the Safety Injection System/Residual Heat Removal System that maintains the pool temperature within a range of admissible temperatures in normal plant conditions. The evaporation rate in the IRWST pool is also dependent on the ambient conditions in the HR. The evaporation rate decreases with the temperature in the HR. Therefore, the IRWST atmosphere is ventilated. This also maintains a sufficient sub-pressure to contain radioactive substances, and ensures proper and efficient operation of equipment (in particular filtration equipment's such as iodine filters) and safe personnel access. Therefore, the evaporative losses of tritium from the IRWST pool are optimised and represent a compromise between these aspects.

947. Discharges of tritium in gaseous effluents can occur due to leaks from systems handling radioactive liquids but these are minimised by good design and plant operation.

948. Small leaks may occur between the primary and secondary circuits through which tritium leaks and appears in the secondary circuit and condensed secondary water. With low pressure in the condenser wet well during operation, some tritiated water can therefore appear in the main condenser off gas. Leaks will be minimised through the use of suitable materials and construction techniques and appropriate maintenance.

949. NNB GenCo (HPC) reviewed and accepted a BAT assessment for the minimisation of gaseous discharges of tritium to air [Ref 157] to contribute to closure of GDA assessment finding UKEPR-AF07 and HPC IC13 arising from the HPC permit application. The BAT assessment has since been confirmed in its applicability to the SZC project, given that it is not concerned with any site specific aspects of the design or operation. It reached the following conclusions regarding design choices to minimise gaseous tritium discharges:

- The EPR^{TM} design enables the operator to adjust the main physical parameters (water temperature) to lower evaporation of fuel pool and IRWST, but it is necessary to consider that these parameters also have an effect for operation and that the control of these parameters is constrained for design and safety reasons.
- For the other sources of tritium discharge (other tanks): Of the 37 other tanks containing primary coolant, 22 are swept by TEG, which limits gaseous tritium discharging to air (See Evidence 143). On the French fleet, the TEP tanks are not swept by TEG and have a huge contribution to total gaseous tritium release. For closed tanks with a vent line, with non-negligible volume, that are not swept by TEG (9PTR tanks and 9TEU/9KER tanks), the contribution to total gaseous tritium release was calculated and deemed negligible.
- For the other tanks not swept by TEG, the BAT assessment [Ref 155] considered their potential contribution to tritium discharges:
    - If the tank volume is very small, (surface volume < 2m^2, the evaporation is negligible and not studied in the BAT. This is the case for three of the remaining tanks.
    - Certain tanks are used only for maintenance or specific operation during outage, the evaporation only occurs temporarily and intermittently for a minimal period of time. For example, certain tanks within the RPE system are only part of a leak detection system and normally remain empty unless one of the connected safety valve discharges into RPE.
    - The remaining tanks consist of closed tanks with only a small vent line to allow filling/emptying. As part of the BAT assessment an estimate of the contribution of these tanks to tritium discharges was calculated. The conservative assessment assuming the maximum level of humidity (and therefore maximum tritium content in the gas expelled

via the vent line when the tank is filled) concluded that the contribution of these tanks would be less than 1% of the total release of tritium from SZC.

- UK EPR^{TM} design enables dilutions to control and limit tritium in RCP during power and when the vessel is open and the HR pools are filled up. This process is a more important way to reduce total tritium in the fuel pool and IRWST and thus, total gaseous tritium release. A tritium management strategy should be applied with a recommendation of the total activity in the pools and make sure the actual activity could not exceed this limit in any case.

950. A number of other possible options to reduce tritium evaporative losses were considered including use of a dedicated cooling air extraction for the fuel building, or use of a pool cover. It was concluded that the minor benefits of these significant design changes would be outweighed by the considerable cost and layout issues associated their implementation, and therefore that they did not represent BAT.

d) Evidence 146: The preferential partitioning of iodine isotopes in liquid effluents

951. Isotopes of iodine, mainly iodine-131 and iodine-133, are formed during the fission process. These also pass into the primary coolant and are purged into the headspace in the RCV tank and then pass to the TEG. Most are retained in the liquid phase, rather than being lost to the gaseous phase in the TEG. In most cases, their activity in the TEG is very low and any discharged are further abated using carbon delay beds in the off gas stream. If required, iodines are also retained in the iodine traps installed in the building ventilation circuits (these iodine traps are brought into service as required).

952. In the UK EPR^{TM}, the majority of gaseous iodines will preferentially transfer to the liquid phase in the TEG, and will therefore indirectly be treated on filters and demineralisers. Liquid iodines are normally largely retained in the RCV demineralisers.

953. The doses for the gaseous and liquid discharges associated with the release of isotopes of iodine, taken from SZC RSR permit application Support Document D [Ref 10], show that the dose to the most exposed members of the critical groups from discharges from SZC are 0.03µSv y^{-1}. Given the proposed discharge limit of, 400 MBq y^{-1} for gaseous I-131 illustrates that discharges of isotopes of iodine have a low impact and release into the marine environment is preferable to discharge to atmosphere.

954. The discharge of iodine in the liquid form is reduced by the abatement techniques previously identified, including recycling of liquid effluent enabling the subsequent decay of short-lived isotopes of iodine.

e) Evidence 147: Retention of iodine in the aqueous phase and subsequent treatment

955. Primary gaseous effluent is processed in the TEG. The recombination unit may help to ensure that iodine in the purge gas in the TEG is returned to and retained in the liquid phase, although to date this effect has not been quantified.

956. The radiological impacts from iodine discharges are lower when discharged as a liquid rather than a gas, which is reflected in the dose assessments for SZC and described in the GDA PCER [Ref 47]. Iodine discharges are preferentially retained in liquid effluents, and they are also abated in demineralisers located in the liquid radioactive waste treatment systems (the TEP and the TEU). However, arisings of iodines are low compared to tritium production even during peak iodine production rates as a result of reactor start-up and shutdowns (refer to Argument 6 for a description of fission product spiking). Activity reduction from demineralisation is relatively modest in terms of radiological impacts, noting the short half-lives of isotopes of iodine [Evidence 142]. Isotopes of iodine which do remain in the gaseous phase are effectively abated by the carbon delay beds due to their relatively short half-lives;

957. The liquid effluent is collected in the RPE for either recycling in the TEP or discharge from the TEP for processing in the TEU prior to discharge.

f) Evidence 148: The preferential partitioning of carbon-14 in gaseous discharges

958. The majority of discharges of carbon-14 into the environment (80 – 95 %) are in the gaseous form, with typically only 5 to 20 % being discharged in liquid and solid wastes. The majority of carbon-14 is degassed during the treatment of the primary effluents in the TEP and directed into the TEG to be discharged as gaseous effluent. Gaseous species containing carbon-14 are not retained in the filters used in the TEG [Ref 5]. It is anticipated that increased recycling of effluents incorporated into the design of the UK EPR^{TM} increases degassing and thus more of the carbon-14 is transferred into gaseous effluent than would otherwise be the case if increased recycling did not take place. However, this cannot be readily quantified because of the complex behaviour of the gas-liquid system and the many variables which influence the partitioning between gaseous and liquid effluents [Ref 5]. The preferential partitioning of carbon-14 into gaseous discharges is advantageous because it is not practicable to partition the activity to solid waste by means of abatement [Evidence 150].

959. The doses for the gaseous and liquid discharges associated with the release of carbon-14, taken from SZC RSR permit application Support Document D [Ref 10], show that the dose to the most exposed members of the critical groups from discharges from SZC are 2.5 µSv y^{-1} and 9.5 µSv y^{-1} respectively. Given the proposed discharge limits of 1.4 TBq y^{-1} for gases and 190 GBq y^{-1} for liquids this results in a dose per unit discharge in terms of µSv y^{-1} per Bq y^{-1} released of 2E-12 µSv Bq^{-1} for releases to atmosphere and 5E-11 µSv Bq^{-1} for releases to the aquatic environment. This illustrates that discharges of carbon-14 to atmosphere is preferable to discharge to the marine environment.

g) Evidence 149: Management of treatment systems

960. The partitioning of carbon-14 between solid and liquid wastes from abatement by demineralisers in the TEP and TEU is not well understood, although in practice discharges of carbon-14 in liquid effluents are low. Carbon-14 is not a targeted nuclide for abatement but is reduced by the abatement of liquid effluents, which is intended for the reduction of more radiologically significant nuclides such as cobalt-60, caesium-137 and caesium-134 from the UK EPR^{TM}.

961. The majority of carbon-14 is degassed during the treatment of the primary effluent in the TEP and directed to the gaseous effluent treatment system to be discharged as gaseous effluent. Some of the carbon-14 contained in the primary effluent may be retained on filters and resins before reaching the TEP, although there are no specific industrial treatments such as filtration for the treatment of carbon-14 in PWRs. The carbon-14 from the non-recyclable effluent may also be retained on filters, resins and in the concentrates from the treatment of the effluent by evaporation.

962. Thus, although the carbon-14 produced must be discharged either as solid, liquid or gaseous effluent, it is estimated that only a small proportion of the carbon-14 initially in the liquid phase is discharged in liquid effluent. However, there are major uncertainties regarding both the concentration of nitrogen in the primary circuit and the distribution between liquid, solid and gaseous discharges, and in particular between solid and liquid waste. These uncertainties are associated with the chemical form of carbon-14, which is a determining factor of carbon-14 behaviour in the plant processes.

963. Reports produced by the IAEA support the GDA PCER [Ref 47] with respect to the partitioning of carbon-14. From the reactor operation described in GDA PCER Sub-chapter 6.3, sections 6.3.2 and 7.3.1, the carbon-14 produced is discharged mainly in liquid or gaseous form, with an estimated ratio of approximately 80 – 95% gaseous and 5 to 20 % as solid and liquid. This is based on operational experience of PWRs. IAEA Technical Report 421 [Ref 142] indicates that the majority of carbon-14 released from reactors is contained in airborne effluents and only a small amount is in the form of liquid effluents while M-S Yim and Caron indicates that 95 % of carbon-14 is expected to be available for gaseous release [Ref 5].

964. EDF has recently undertaken work to better understand the behaviour of carbon-14 in PWR radioactive wastes. From the data obtained so far by EDF and from the EPRI work, it is concluded that the reactor coolant treatment and liquid effluent treatment systems do remove some carbon-14 from liquid effluent but that much of the

carbon-14 remains in the effluent. It is not possible to provide detailed quantification on this beyond the report on Paluel NPP. Further studies are ongoing at other French stations to confirm the results obtained at Paluel and build up the OEF necessary to determine the need or otherwise for further action with respect to carbon-14 in liquid effluents.

965. On the basis of the limited information available, which is discussed above, it appears that it is not possible to fully control the partitioning of carbon-14 between the solid, liquid and gaseous phases, other than maximising the amount in gaseous effluent by means of maximising the efficiency of the degasification process for the primary circuit. This is considered to be BAT to minimise radiological impacts of carbon-14 discharges. There is some partitioning between liquid and solid wastes, but the complex redox chemistry associated with carbon-14 is poorly understood due to its complexity. The liquid effluent treatment systems are optimised for control of coolant chemistry for the purposes of safe reactor operation and minimisation of worker radiation doses.

h) Evidence 150: Carbon-14 in solid waste

966. It is recognised that the carbon-14 concentration in solid wastes, in particular ion exchange resins and cartridge filters, can cause problems with their management, particularly in the UK, and that the limits set for waste repositories are restrictive (section 8 of IAEA Technical Report 421 [Ref 142] provides some information on waste acceptance requirements and storage and discharge options). Wastes that could otherwise be managed as LLW may be restricted from discharge to the UK LLWR because of their carbon-14 content and therefore have to be disposed of as ILW. Carbon-14 is a key nuclide in the LLWR’s Post Closure Safety Case and is carefully limited in the LLW consigned for discharge to mitigate the fact that it has a high potential mobility and in theory could diffuse into groundwater. The timescale of such a release from the repository would be short in comparison to the half-life of carbon-14 (5,730 years). For these reasons, concentrating carbon-14 in solid waste is not considered as BAT [Ref 5].

6.4.2 Claim 4, Argument 21: An appropriately designed Liquid Effluent Discharge System will minimise impacts of radioactive discharges to the environment

967. Throughout the design and operation of SZC, BAT will be used to minimise liquid discharges. Those liquid effluents that are unavoidably produced need to be released in a manner which minimises impact to people and the environment.

968. The management arrangements for the liquid effluent discharge system at SZC have not yet been fully defined. However, the fundamental aspects will be consistent with international best practice, which are:

- The use of the TER to minimise discharges. Effluents are stored and monitored to ensure they meet the required chemical, physical and radioactive parameters to allow discharge to occur and the capability to transfer effluents back to liquid effluent treatment systems for further treatment in the event that the required parameters are not met [Evidence 153].
- Discharge of radioactive liquid effluents to the Outfall Pond and Outfall Tunnel into the North Sea to achieve the maximum achievable dilution by non-radioactive cooling water. The installation at SZC will have a single common discharge outfall tunnel for the two UK EPRTM units, which will have an internal diameter of approximately 8m and will be bored at depth under the shore and seabed from landward in a manner similar to that of the Intake Tunnels, before rising to a pair of seabed mounted outfall structures. The large volume of seawater from the cooling outfall provides the dilution which minimises the impacts of discharge to the marine environment [Evidence 152].
- To maximise dilution and dispersion in the marine environment by means of final discharge into the sea at a sufficient distance from the shore to ensure that the radioactive effluents, already diluted by cooling water, are further diluted and dispersed in the marine environment. The discharge outfall head will be bored beneath the seabed and located approximately 3.5 km off-

shore and provides sufficient dispersion of activity discharged from the Outfall Tunnel [Evidence 152].

- The management of discharges to take account of tidal, hydrological and geomorphological features and other factors that could affect the dilution and dispersion of radioactive liquid effluents. The arrangements will be defined at the appropriate stage in the development of the installation.

969. Environmental impacts are minimised by reducing the concentration and accumulation of radioactivity in radiation exposure pathways. These are assessed by means of the Environmental Monitoring programme which samples and analyses materials from the environment for radioactive content. This is discussed in RSR Permit Application Support Document C.2 [Ref 7]. The sampling, measurement and assessment of discharges are discussed in RSR Permit Application Support Document C.1 [Ref 6].

6.4.3 Sub-Argument 25: Discharge of Liquid effluent from major discharge points

970. Three major discharge routes have been identified. The discharge point of each of these routes is the Outfall Tunnel:

- The KER collects treated effluent from a number of sub-systems on-site, including the TEU and APG. The KER is the principle route for discharging radioactive effluents;
- The TER provide buffer capacity for the same systems serviced by the KER and can be transferred by the same pipework to the outfall pond, or enable out of specification effluents to be routed back to the TEU for further treatment. The TER also provides reserve capacity for the SEK and IRWST; and,
- The SEK collects effluents that are not chemically or radioactively contaminated, such as waste water from the turbine hall. Discharge from the SEK is likely to be of minor significance as in normal conditions would not be contaminated; the segregated system means that contaminated effluents are kept separate from active effluent streams. As the contribution to discharges cannot be demonstrated in advance of operation, the discharges have been identified as a major route.

a) Evidence 151: Discharge of radioactive liquid effluents to the Outfall Pond and Outfall Tunnel and maximising dilution and dispersion in the marine environment

971. The systems for storing and discharging the liquid radioactive effluents are on the one hand designed to check and quantify the activity of the effluent before discharging it, and on the other hand to minimise the impact of liquid radioactive effluent on the environment by achieving optimal dilution and dispersion.

972. The cooling water plume mixes into the sea and covers a large area which will be effective in promoting maximum dilution of liquid radioactive effluent and thus reducing its environmental impact.

973. Liquid effluents from the KER, TER and SEK discharge effluents to the outfall pond HCA1 through the outfall pond building (HCA). However, when the outfall is undergoing maintenance, these systems could not discharge the effluent. An optioneering study identified that the BAT option would be to add common discharge lines to the HCA2 outfall pond via the Demineralisation Station Gallery (HGY), allowing for the effluent flow from the KER, TER and SEK to be diverted to either the HCA1 or HCA2 according to availability.

974. Significant dilution is achieved in normal operation due to the discharge flow rates involved therefore minimising environmental impact. The worst-case dilution cooling water flow rate scenario is based on the maximum annual discharge of 116 m^3 s^{-1} based on the standard operation of a single UK EPR^{TM} unit having a minimal operational cooling water flow of 58 m^3 s^{-1} under low tide conditions. So even at the lowest flow, a significant dilution factor is achieved.

975. The installation at SZC will have a common discharge Outfall Tunnel for the two UK EPR^{TM} units, which will have an internal diameter of approximately 8 m. The large volume of seawater from the Outfall Pond provides the dilution which minimises the impacts of discharge to the marine environment. Final discharge into the sea will be at a sufficient distance from the shore to ensure that the radioactive effluents, already diluted by cooling water, are further diluted and dispersed in the marine environment. The discharge outfall head will be located approximately 3.5 km off-shore. The location and design of the discharge outfall has been optimised on the basis of detailed marine dispersion modelling in the proposed area.

b) Evidence 152: Use of the Additional Liquid Waste Discharge System to minimise discharges

976. The SZC KER and SEK tanks include the capability to transfer effluent to the discharge tanks located in the TER, in the event that discharges to the environment from the KER and SEK is not possible. It is possible to either store the effluent in the TER for future discharge or transfer the effluent from the TER for additional treatment. This safety related capability provides an additional environmental protection measure, and a potential opportunity for reducing activity discharged.

977. This TER storage capacity may be used during exceptional situations when, for example:

- dilution in the natural environment cannot be performed by normal discharge methods due to the unavailability of the KER or SEK tanks; or,
- complete saturation of the TEU head tanks; or,
- the need to drain a high-volume capacity (for maintenance or in the event of failure) containing effluent, which cannot be discharged via normal means, i.e. PTR tank or RCV tanks for water make-up of the primary system; or,
- high activity of effluent from the turbine building which is normally discharged by the SEK; or,
- an unexpected operating incident disrupts the normal operation of a unit preventing direct discharge via normal means.

978. The role of the TER is thus to store the site liquid radioactive effluent:

- either to re-treat it using the TEU; or,
- to discharge it later to the environment.

c) Evidence 153: Prevention of unmonitored discharges to the marine environment

979. Discharges of radioactive liquid effluent from SZC are subject to conditions of the RSR permit for the plant to sample, monitor and analyse the effluent to ensure compliance with permit conditions. SZC employs a flow meter and flow proportional sampler (FPS) on the final discharge from the KER and SEK tanks for this purpose [Evidence 178]. A modification [Ref 124] to the design has been made to link the final discharge valves to the flow and proportional samplers such that if they are offline there will be no discharge to the environment. This is BAT because although it is calculated that any impact on the environment would be low (in-process monitoring of the KER and SEK tanks allows any abnormally high activity effluent to be recirculated) this design change will prevent any inadvertent and unmonitored discharge to the marine environment.

980. The KER and SEK discharge line both have 1 flow meter and FPS. Given that failure of either of these devices will result in discharges being stopped, and taking into account factors such as additional maintenance and available space, it is not deemed proportionate to have secondary FPS or flow meter devices. In the event of the discharge not being stopped, or prolonged unavailability, back up methods such as tank level readings and tank samples can be taken to provide a representative sample if a discharge is carried out.

d) Evidence 154: Maintenance and Inspection of Outfalls

981. In order to carry out periodic inspection of the outfall tunnel a ROV will be used. The inspections will involve the lowering of a Saab Sabertooth (or similar/improved) inspection ROV through a vertical shaft at the interface point between the 2 onshore outfall galleries and the outfall tunnel. From this point, the ROV will swim down the outfall tunnel and back again, to be recovered from the same shaft. The inspection process will last 1 working day. It is planned to be performed at a 10 yearly frequency during the major outages.

982. The addition of the vertical shaft to carry out inspection was done under design change DDM CNEPEGT5032UK. During the period of inspection, the ability to discharge from the Site Discharge Systems KER, TER and SEK will be limited. This is covered by the BAT assessment [Ref 159].

6.4.4 Sub-Argument 26: Discharge of Liquid effluent from minor discharge points

983. There are a number of other liquid effluent systems on the SZC site that are not identified as major discharge routes. In all cases it is expected that these effluent streams will not normally contain radioactive material but in certain situations the presence and detection of trace quantities of radioactivity cannot be ruled out from these effluent systems. These systems are:

- Water run-off collection systems from on-site and off-site car parks (Collection and Storage of Oils and Hydrocarbon Effluents (SEH)) and from buildings (SEO-EP system) that are routed through to the Forebay prior to discharge via the outfall tunnel.
- Return line of circulating seawater cooling system.
- Spillway designed to return seawater from each units Forebay in the event of cooling water pump failure coinciding with high tide.
- Sea wall drainage system returns rainwater and wave topping of the sea wall.

a) Evidence 155: Discharges from the Collection and Storage of Oils and Hydrocarbon Effluents system

984. It was decided that oily, potentially contaminated water from the SEH should be stored at source, in bunds or sumps, rather than in an Attenuation Pond (HXO) included in the original GDA design. This is considered an improvement over the original design as it allows for improved treatment of the water at the source and the removal of a single HXO which may not have had the capacity to manage all the water discharges.

6.4.5 Claim 4, Argument 22: Appropriately designed Gaseous Discharge Points will Minimise Impacts of Radioactive Discharges to the Environment

985. There will be two principle radioactive gaseous discharge routes for SZC:

- The Unit 1 HN Stack.
- The Unit 2 HN Stack.

986. There will also be minor discharge points. These are defined in detail in SZC RSR Permit application head document [Ref 1], but will include the HHI for ILW, and the main steam release train.

987. Whilst the gaseous waste that will be discharged from the SZC station will contain only minimal levels of radioactivity, the manner in which it is discharged can nonetheless affect the potential impact of the discharge on humans and the environment. It is therefore necessary to optimise the discharge to ensure that it represents BAT. In terms of gaseous discharges, this essentially means ensuring optimum dispersion of the radioactive discharges and is primarily influenced by stack height; the velocity and temperature of the exhaust gas, as it is discharged. These design features will be discussed and described in [Evidence 157].

988. The gaseous waste processing system at SZC, when coupled with a number of other design features, will ensure that radioactive waste is disposed of at times, in a form and in a manner that minimises the radiological effects on the environment and members of the public.

a) Evidence 156: Design of the height of main discharge stack to ensure optimisation of gaseous discharge dispersion in the environment

989. The height of the SZC main discharge stack has been determined [Ref 160] taking into account the proportionality principle to ensure optimisation is achieved when any additional increase of the stack height would incur costs that are grossly disproportionate to the benefits to dispersion provided. The report considered the benefits and disbenefits of any change to the stack height of 70m established in the SZC reference design (which is the same as that specified for the HPC RC2 reference design). The assessment of stack height considered:

- A SZC stack height sensitivity study, which evaluated the impact of stack height on the dispersion and ground concentration of radionuclides from routine gaseous releases at reference locations close to the SZC site. The stack height sensitivity study demonstrates that the dispersion factors could vary by around a factor of three across the range of stack heights considered (65-80m). A height of 75m can be broadly considered to align to the point of inflection where the rate of decrease in the dispersion factor starts to flatten out. The distances at which maximum dispersion factors occur are within the proposed SZC site boundary.

- Radiological dose impact assessment for the representative (most exposed) members of the public from routine discharges for incremental stack heights (above the reactor building) on the basis of conservative assumptions described in the Environment Agency Initial Radiological Assessment Methodology. The assessment showed that the dose impact associated with gaseous releases from SZC may vary by around a factor of two for the range of physical stack heights considered (65-80m). However, the actual doses from gaseous discharges are of the order of a few micro-Sieverts and well below the threshold of optimisation (10µSv/y).

- Consideration of operational safety issues including on-site impacts to workers and accident release scenarios. It also considered conventional non-radiological safety associated engineering aspects (construction and maintenance) of the gaseous emission stacks. This section of the report was largely based on the work undertaken for the HPC stack height assessment [Ref 161] and concluded that the impacts of the 5m stack height increase at SZC (over HPC) may have a slight detriment to conventional safety (construction and maintenance activities) but an insignificant impact on radiological safety (off-site dose in accidental operation) or no difference to the on-site dose to workers.

- Evaluation of technical considerations and cost elements associated with the construction and maintenance of the emission stacks (including HVAC systems). This section of the report was largely based on the work undertaken for the HPC stack height assessment [Ref 161] and concluded that the 5m increase in stack height of SZC (over HPC design) would have no difference in the cost of design of the stack or HVAC system but would have significant cost implications for construction. The minimum stack height of 70m was therefore considered the most cost effective option.

- Consideration of landscape and visual impacts associated with the gaseous emission stacks in the context of the sensitive environments around the SZC site and the attendant planning constraints and risks. The area around SZC is predominantly rural, flat and dominated by agricultural land and semi-urban and coast environments. SZC lies within the Suffolk Coast and Heaths Area of Outstanding Natural Beauty and is therefore sensitive to visual intrusion from tall structures that would be visible over long ranges. This was also raised as a key concern of local stakeholders in preliminary consultation. Deliberations undertaken for the HPC development determined that it would be difficult for developments with structural heights greater than 80m to pass through the planning process without strong justification that it was necessary for safety or environmental reasons.

990. The report included an assessment of potential doses to members of the public using conservative assumptions indicated annual doses of the order of 2.1µSv/y reducing to 1.2µSv/y for physical stack heights in the range 65m to 80m. These doses are well below the 10µSv/y criterion of ‘potentially of no regulatory concern’. This dose assessment was undertaken specifically to assess the stack height, and is not the same as the more realistic dose estimates undertaken as part of this permit application [Ref 10].

991. The report concluded that potential impacts from accidental release scenarios are independent of the stack height. The dose consequence to site workers from accidental and routine discharge scenarios have been shown to be mitigated through site procedures and are therefore not affected by the physical height of gaseous emission stacks.

992. The consideration of planning requirements and stakeholder concerns regarding landscape and visual impacts would support the adoption of the minimum stack height that satisfies the BAT criteria. A 70m stack will be 6m higher than the domes of the reactors which would minimise the visual impacts of the structure. Higher stacks are considered likely to face significant challenge by stakeholders. In addition, the construction cost of an emission stack increases with the square of its height. A 5m increase in stack height is expected to entail relatively higher costs.

993. Table 6-4 below provides an indication of the impacts associated a 5m increase in stack height:

Table 6-4 Impacts due to 5m stack height increase

Aspects	Factors	Impact of increase in height
Environmental Impact	Dispersion factors	Increased dispersion with every 5m increase up to 75m. Rate of change reduces after 75m and the benefit of increased height diminishes.
	Ground level air concentrations	Less than 10% reduction in difference at most sensitive habitation.
Operational radiological safety	Off-site doses to members of the public in routine conditions	Less than 0.5 Sv/y reduction in dose.
	Onsite doses to workers in routine conditions	No differences.
	Off-site doses to members of the public in fault condition	Insignificant impact.
	On-site doses to workers in fault condition	No difference.
Conventional safety	Industrial safety (construction phase)	Slight increase in risk.
	Industrial safety (operational phase)	Slight increase in risk.

Visual impact	Visual impact	Increase in detriment.
Cost	Design of stack, monitoring and HVAC systems	Increase if different to 70m HPC design.
	Procurement costs	Increase if different to 70m HPC design.
	Construction cost	Increases with height due to increased cost of materials and supporting structures.

994. The outcome of the stack height assessment for SZC recommended that the main unit stacks be set at a height of 70m. This recognised the lowest stack height allowed by regulatory guidance, the requirement to minimise the impact of radiological discharges and minimise the loss of visual amenity, and the benefit of replicating the HPC design.

b) Evidence 157: Discharges to Atmosphere from Interim Storage Facility for Spent Fuel and Interim ILW Store

995. During the storage of spent fuel gaseous tritium may escape the fuel cladding however it is not expected to pass through the cask since it is welded, leak tight containment that is justified to maintain containment of the helium atmosphere for 120 year storage life. If tritium were to escape it would be at very low rates and low activities to the point where no worker protection controls would be required within the facility. In this instance the discharges would be a very small fraction of the proposed site limit for gaseous tritium [Ref 162].

996. During the storage of ILW within the Interim ILW storage facility a small quantity of tritiated gas could evolve in the packages and diffuse through the package. This is expected to be at low rates and low activities to the point where no worker protection controls will be required within the facility. The discharges will be a very small fraction of the proposed site limit for gaseous tritium Claim 4, Argument 21, Doses from direct and sky shine from the storage of spent fuel and ILW are minimised.

6.4.6 Claim 4, Argument 23: Doses from storage of spent fuel and ILW will be minimised

997. There will be a dose to the public from the HHI and HHK as a result of direct and sky shine radiation. The design of the facilities will minimise this dose SFAIRP.

a) Evidence 158: Doses from storage of spent fuel and ILW will be minimised

998. The detailed design for both spent fuel and ILW waste packages is currently underway for HPC, this is intended to be replicated, as far as possible for SZC. The ILW waste packages and HHI will be designed and operated to reduce dose to members of the public SFAIRP [Ref 167]. The spent fuel dry storage casks will be designed to reduce the doses to the members of the public from direct and skyshine SFAIRP [Ref 32]. The spent fuel inspection facility and encapsulation plant will be designed and operated to reduce doses to members of the public SFAIRP, this facility is planned, however, it will not be designed and constructed until later in the operation of the plant.

6.5 Claim 5: SZC Co. shall undertake appropriate monitoring to check compliance with the conditions of the RSR permit

999. Monitoring is undertaken to check compliance with the conditions of the RSR permit, in particular to ensure that:

- the generation of radioactive waste is prevented or minimised at source;
- wastes are adequately segregated;

- the treatment and disposal of radioactive waste are optimised;
- systems and components serving an EPF are operating normally and efficiently;
- the amount of radioactivity discharged or disposed of to the environment is minimised;
- radioactive discharges remain below the limits set in the RSR permit;
- if a QNL is exceeded the source of the excess can be identified;
- the volume of radioactive waste disposed to other premises is minimised;
- the WAC for the relevant waste disposal routes are complied with; and,
- the impacts on the environment and members of the public from radioactive discharges to the environment and radioactive waste disposals to other premises are minimised.

1000. This claim therefore supports and complements claims 1, 2, 3 and 4.

1001. In-line with the scope of this document, this claim is concerned primarily with monitoring with respect to the plant (i.e. radioactive waste process, and radioactivity monitoring). Other forms of monitoring, such as of the competence and capability of the organisation (People) or Quality management arrangements (Process) are out of scope of this claim and are covered in the SZC RSR Permit Application head document – management arrangements sections [Ref 1].

1002. [SZC RSR CMT1] of the Forward Work plan set out in the SZC Permit Application head document [Ref 1] sets out how SZC Co. will ensure that organisational learning is successfully implemented on the SZC project. This will include ensuring that the monitoring techniques implemented at SZC continue to remain up to date and take advantage of changes in best practice, where it is demonstrated that this represents BAT.

1003. Monitoring includes sampling and online measurements (which may also be referred to as online monitoring).In the context of radioactive solid wastes, monitoring includes waste characterisation, clearance monitoring and assay of waste packages. When referring to solid wastes, non-aqueous waste streams such as oil and sludge are implicitly included.

1004. Analysis and assessment in order to check compliance with the RSR permit is also considered under this claim. Analysis is referred to in its broadest sense i.e. online measurements, tests, surveys and laboratory analyses. Monitoring undertaken at SZC comprises a range of features which contribute to substantiating this claim. These features are presented in the arguments that sit under this claim.

1005. Figure 6-12 shows the overarching structure of the Claim, Argument, Sub Argument and Evidence for this Claim. However, as each Argument contains several Sub Arguments, for clarity, individual figures are also included for each Argument to fully illustrate the details of the structure (see Figure 6-13 – Figure 6-17).

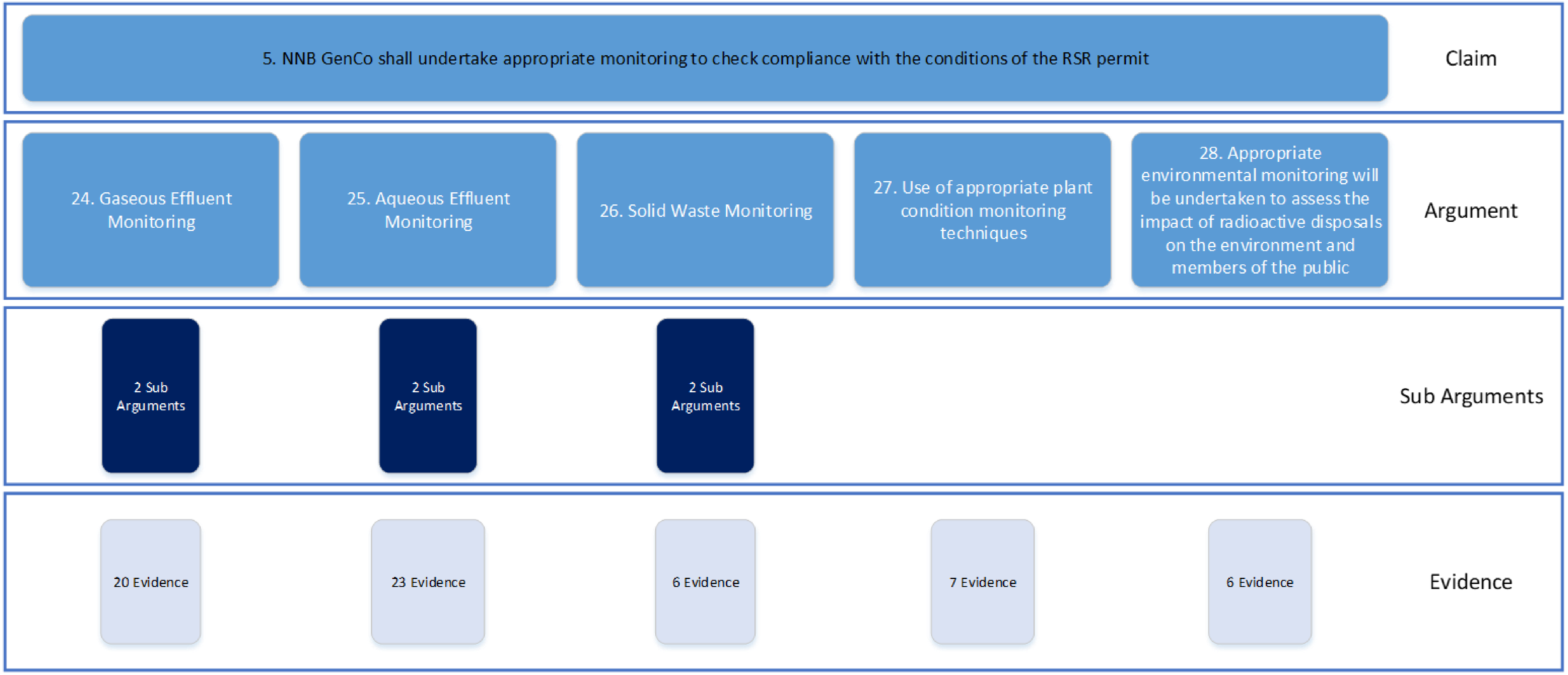


Figure 6-12 Overarching Structure of Claim 5

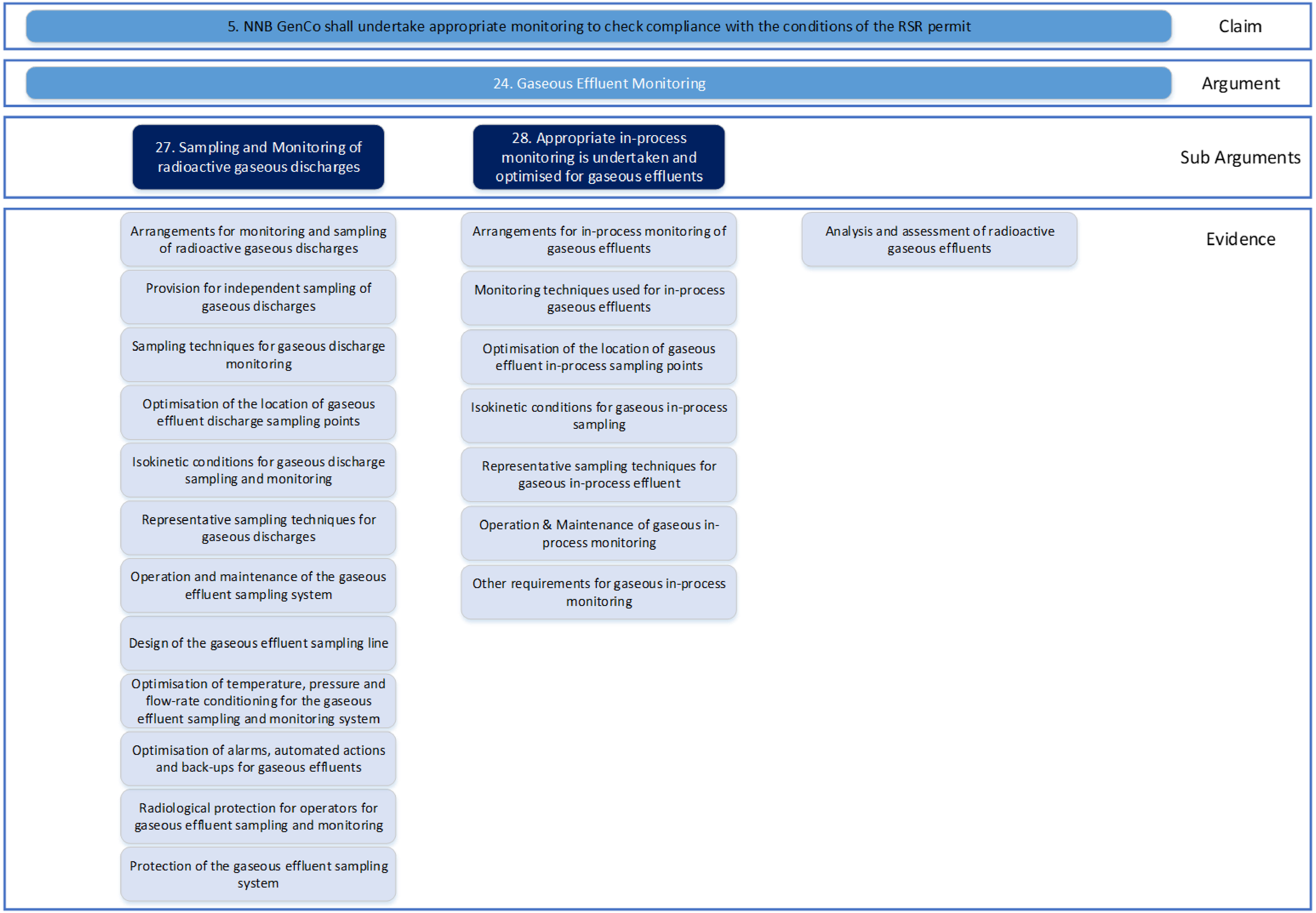


Figure 6-13 Structure of Claim 5 – Argument 24

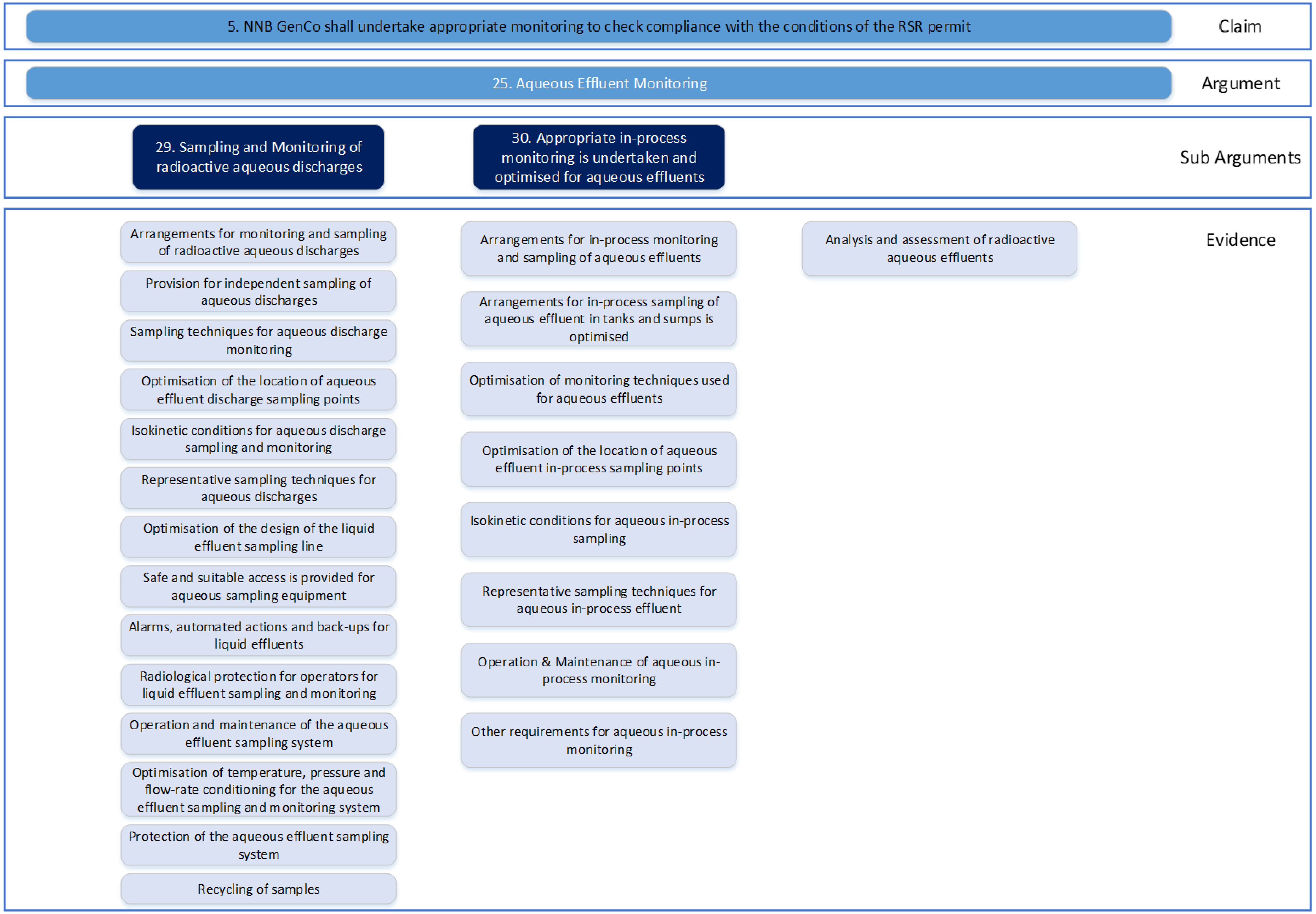
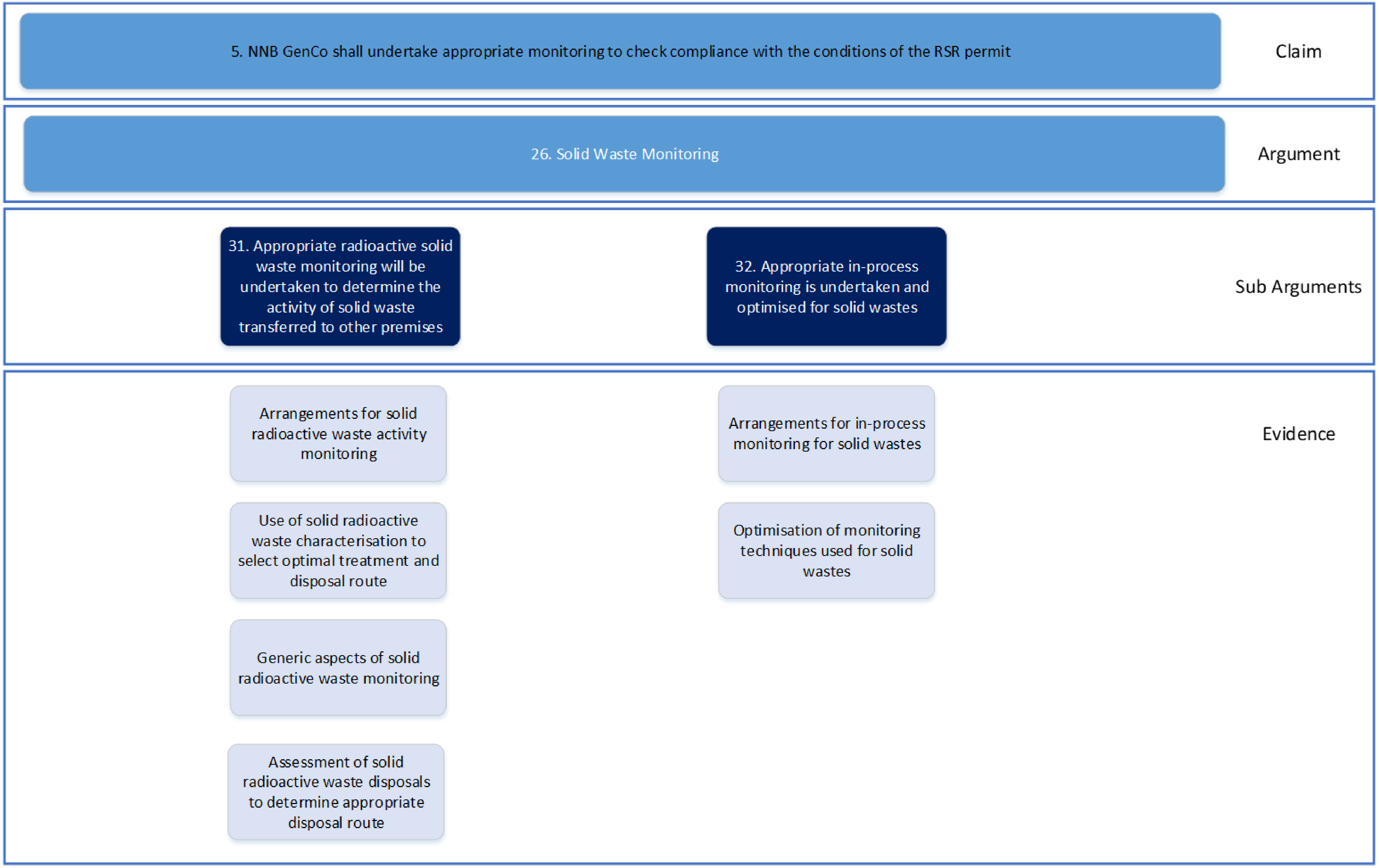


Figure 6-14 Structure of Claim 5 – Argument 25



Claim

5. NNB GenCo shall undertake appropriate monitoring to check compliance with the conditions of the RSR permit

Argument

26. Solid Waste Monitoring

Sub Arguments

31. Appropriate radioactive solid waste monitoring will be undertaken to determine the activity of solid waste transferred to other premises

32. Appropriate in-process monitoring is undertaken and optimised for solid wastes

Evidence

Arrangements for solid radioactive waste activity monitoring

Use of solid radioactive waste characterisation to select optimal treatment and disposal route

Generic aspects of solid radioactive waste monitoring

Assessment of solid radioactive waste disposals to determine appropriate disposal route

Arrangements for in-process monitoring for solid wastes

Optimisation of monitoring techniques used for solid wastes

Figure 6-15 Structure of Claim 5 – Argument 26

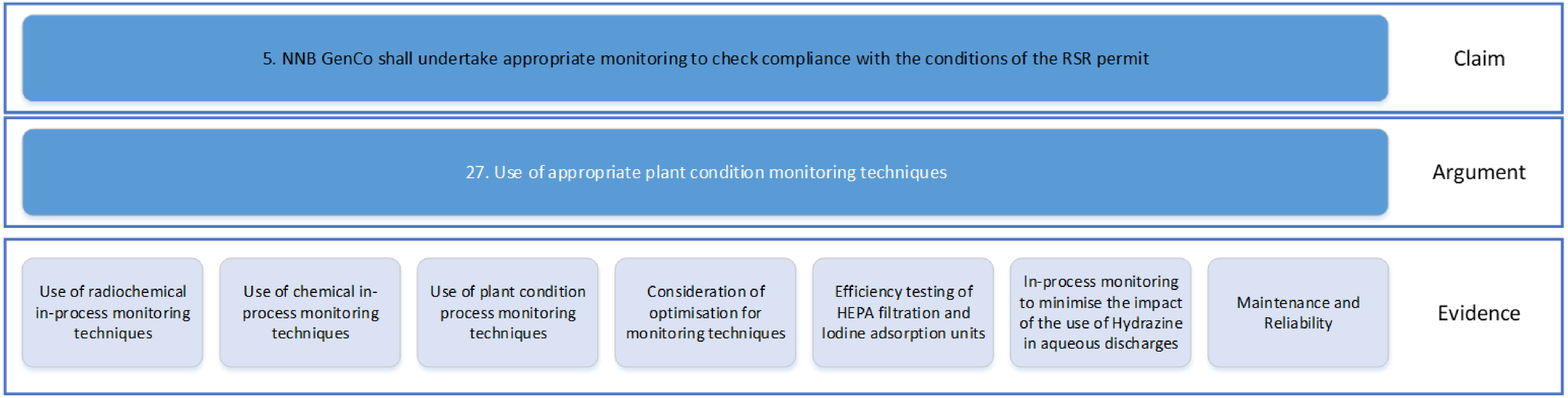


Figure 6-16 Structure of Claim 5 – Argument 27

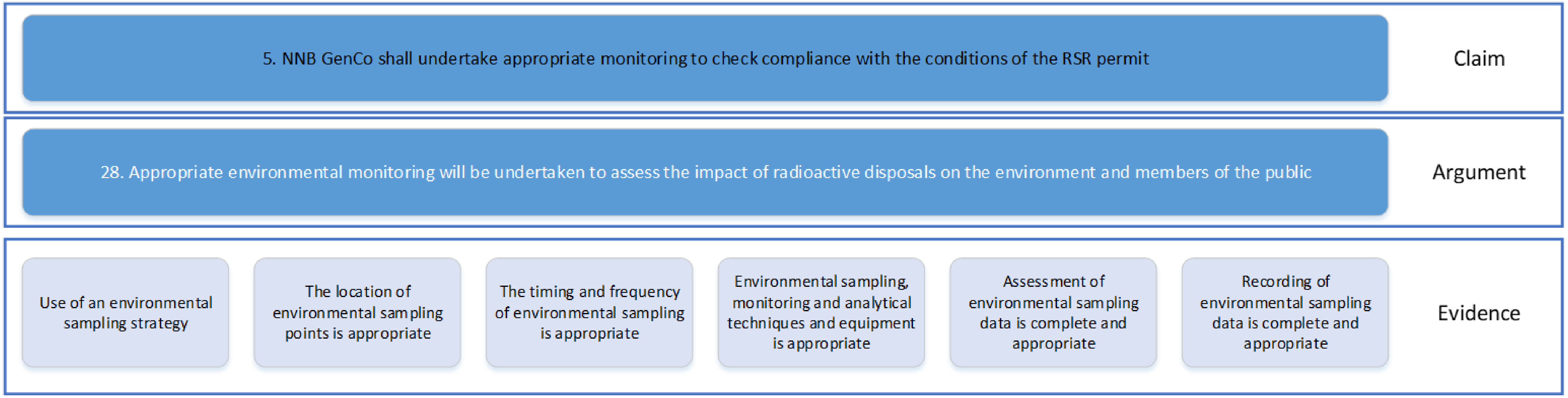


Figure 6-17 Structure of Claim 5 – Argument 28

6.5.1 Claim 5, Argument 24: Gaseous effluent monitoring

1006. Gaseous discharges from the main outlets at SZC (HN stacks) will be monitored continuously to allow assessment and reporting of discharges, and to check compliance with the discharge limits and QNLs specified in the RSR permit.

1007. Certain radionuclides may be monitored on-line continuously whilst others may be sampled continuously, with periodic collection of samples and laboratory analysis. The choice of the monitoring approach chosen for each radionuclide or groups of radionuclides will take account of international best practice and will be proportionate to the complexity of the measurement and to the potential risks from the discharge. Where monitoring is required in order to demonstrate compliance with the RSR permit, suitable redundancy is provided in the event of equipment failure.

1008. Discharges from the minor outlets will not be continuously monitored. However, discharges from these outlets will need to be assessed to check that emissions from these outlets remain below 5% of the respective discharge limits specified in the RSR permit. The minor outlets will either be monitored through the use of spot samples or calculated based on process data. This is regarded as proportionate to the level of risk associate with the very low levels of discharges released from these outlets.

1009. In-process monitoring is aimed at providing information to demonstrate that the operations giving rise to radioactive effluent and the use of abatement plant and all associated control and management systems are performing as planned.

1010. Monitoring results in the TEG and the active-HVAC systems will be used to optimise the operation of the plants where gaseous effluents are produced, and to detect elevated discharges that may indicate that BAT is not being applied, and allow suitable operator actions to be taken to rectify the situation. For the active-HVAC systems, in-process monitoring is key for enabling automated switchover to iodine filtration on the detection of significant activity.

6.5.2 Sub-Argument 27: Sampling and monitoring of radioactive gaseous discharges

1011. The design of sampling lines for radioactive gaseous discharges is underpinned by the following features:

- Monitoring of appropriate radionuclides, at an appropriate frequency;
- Consistency with international best practice;
- Compliance with relevant (Environment Agency) Monitoring Certification Scheme (MCERTS) standards, where applicable;
- Consistency with relevant national and international standards, in particular:
    - BS EN IEC 60761 (2004) - Equipment for continuously monitoring radioactivity in gaseous effluents;
    - IEC 62302 (2007-01) - Radiation protection instrumentation - Equipment for sampling and monitoring radioactive noble gases;
    - BS ISO2889:2010 - Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities; and,
    - KTA 1503.1. – Monitoring the Discharge of Radioactive Gases and Airborne Radioactive Particulates.
- Consistency with regulatory and industry guidance and codes of practice; including the EA’s

Radiological Monitoring Technical Guidance Note M11 (now Environment Agency Technical guidance 245_17) [Ref 168].

- Appropriate location of sampling points, in particular:
    - Sampling point to be preferentially placed in a zone where the flow is strongly turbulent to facilitate good mixing, but far enough from any point that could disturb the flow or where interfering effluent may arrive (if this cannot be achieved these conditions will have to created artificially, e.g. using baffles or spillways).
    - Sampling point to be preferentially placed with an immersion at least equal to a third of the pipe hydraulic diameter and far enough from the pipe wall.
    - Sampling point to be as close as possible to the component to sample.
    - Sampling point located in the range of 5 to 10 hydraulic diameters downstream of a flow disturbance and 3 or more hydraulic diameters upstream of a flow disturbance.
    - Sampling point to be downstream of any abatement plant but upstream of any point where further dilution of the waste stream occurs.
- Isokinetic sampling of particulates, in particular:
    - The rate of sampling must match the rate of flow in the pipe or duct (velocity and concentration).
    - Sampling probe ideally to be pointing upstream, preferably at an angle of 180° to the direction of flow.
    - Selection of a probe with a nozzle.
- Appropriate design of the sampling system to ensure representative sampling, in particular:
    - The flow in the sampling line should ideally be turbulent.
    - Deposition rate, condensation and plate-out effects have to be ALARP (notably sufficient velocity in the sampling pipe and trace-heated pipe).
    - Use of inert and corrosion resistant materials (ideally stainless steel).
    - Minimisation of the length of pipe between the probe and the sample collector/on-line monitor.
    - Minimisation of bends in the sampling line. If bends cannot be avoided, they must be gradual.
    - Location of valves and other equipment such as pumps to be downstream of the sample collector/on-line monitor and prevent bypass of the sample collector/on-line monitor during sampling or on-line measurement;
    - Sampling carried out well away from any ductwork features such as dampers, bends and merged streams, which may have a detrimental effect on mixing and flow patterns.

    Alternatively, demonstration of a well-mixed flow at the plane where the sample is taken is required.

    - Minimisation of internal roughness on sampling pipe walls as far as reasonably practicable.
    - Prevention of particulate matter deposition downstream and/or carrying over to the analysis stage, by use of a particulate filter in the sampling probe.
    - Testing using appropriate tracer or comparing results of analysis of samples taken at different points to demonstrate representativeness. Results of tests must be in the range of values specified in the norms.
- Appropriate consideration of operational and maintenance requirements, in particular:
    - Back up is provided for the essential components of the sampling system (e.g. pumps) where high reliability of the sampling system is required.
    - There is safe and easy access to sample collectors/on-line measurement devices for maintenance activities.
    - Appropriate facilities and services are provided to the sampling/on-line measurement system for routine and maintenance operations (e.g. electricity, lighting and water).
    - There is sufficient space for maintenance equipment and personnel.
    - Sampling collector locations to be safely and easily accessible for operational activities.
    - Sounding/display of an alarm in case of equipment failure or authorized limits being exceeded and appropriate automatic actions.
- Consideration of civil work constraints.
- Consideration of operator radiation protection e.g. valves with « remote » command, use of gloveboxes, appropriate shielding etc.
- Appropriate disposal/recycling of samples.
- Appropriate temperature, pressure and flow-rate conditioning of the effluent in the sampling line.
- Protection of equipment from environmental conditions and people interference where needed (e.g. sampling/on-line equipment placed in locked cabinet, bubblers protected from heat or cold (freezing) etc.).

1012. In addition to the design aspects, the following aspects contribute to demonstrating BAT for the sampling techniques:

- Appropriate sampling equipment is selected.
- Appropriate sampling procedure in line with relevant standards and regulatory guidance.
- The size of samples is commensurate with that required by the analysis laboratory and with provision of spare material for repeat analyses and (if required) sample archiving.

- Appropriate arrangements for testing and calibration of equipment.

a) Evidence 159: Arrangements for monitoring and sampling of gaseous discharges

1013. Sampling equipment will be provided at each main discharge outlet to allow the measurement and assessment of radionuclides subject to discharge limits. It should be noted that, depending on the technique selected, the monitoring of some radionuclides might involve in-situ plant measurements with no requirement for a sample.

1014. Environment Agency guidance on standardised reporting of discharges [Ref 163] notes that routine monitoring should be undertaken where it is technically feasible and where it provides a more appropriate assessment of the discharge than a calculation method, but calculated/estimated discharges will be acceptable where they are more accurate than measurements. The monitoring/sampling arrangements outlined here are intended to allow actual measurement of all significant radionuclides relevant to demonstration of compliance with the discharge limits proposed in RSR Permit Application Support Document B [Ref 2], to limits of detection recommended in EU commission recommendation (2004/2/Euratom) [Ref 164]. The final detection limits achievable by the monitoring/sampling arrangements are still to be determined, however if technical constraints result in the detection limits in the EU Commission recommendation not being achievable, calculation/estimation of discharges may be considered.

1015. Following sampling, the next stage for the determination of radioactivity discharged involves measurements and assessment, where the discharge assessment brings together the sample analysis result and the volume of effluent sampled and discharged, so that a final discharge value can be calculated and reported. In-situ measurement techniques provide real-time discharge data, which is recorded to complete the discharge assessment.

1016. Accurate measurement and recording of flow rates in all main discharge outlets and associated sampling equipment is essential for producing adequate discharge assessment results and for achievement of representative sampling. Flow rate measurements are also used to control and monitor the sampling and discharge process and to provide an indication that relevant equipment is operating correctly. The selection of the flow rate measurement equipment for SZC will depend on the sampling techniques and equipment chosen, as they are part of the sampling techniques for the determination of all the limited radionuclides of interest.

1017. A report has been produced to support the design of the stack monitoring and sampling systems. The objective of the BAT assessment [Ref 165], was to analyse possible options for the design of KRT sampling lines used for monitoring HN stack discharges given that the stack height for SZC was significantly different to that on FA3. As such the report presented three options to ensure that suitable sampling arrangements were in place for the SZC stack:

- **Option n°1 (Baseline):** FA3-Type Design, this design comprises 5 sampling lines installed along the length of the stack.
- **Option n°2:** ISO2889-Type Design, this design is based on a configuration that features in International Standard ISO2889:2010 on sampling radioactive materials from nuclear facilities. It comprises one main sampling line in the stack that feeds secondary sampling lines in the HN (design shown overleaf).
- **Option n°3:** Hybrid Design, which was defined comprising three sampling lines. It is a combination of both Options 1 and 2. The report presents the full analysis but in summary, Option 1 was ruled out as both particulate and tritium sampling is less representative compared to the other options under evaluation.

1018. Option 2 may also allow for better tritium sampling (than option 1) due to comparatively less condensation occurring (if condensation does indeed occur). The design does however have some disadvantages: there are system/cost/layout impacts associated with the primary sampling pumps (an addition compared to Option 1) and with extending the safety classification to the whole sampling circuit. Technical feasibility may need further consideration and absolute performance for particulate sampling does not fully comply with ISO2889:2010.

1019. Option 3 provides the benefits of Option 2 with fewer disadvantages and therefore the overall impacts of Option 3 are considered proportionate to the environmental gain of having improved sample representativeness for tritium and particulates.

1020. [Ref 161] has been carried out for the design of HN Stack Discharge Monitoring Provisions on the SZC UK EPR^{TM}. This report assessed a number of options:

- **Option n°1**: Baseline – Use existing monitoring provisions and strategies. This is the current design on FA3.
- **Option n°2a**: Online “PIG” monitor: Sizewell B use Particulate, Iodine and noble Gas (PIG) devices to monitor the discharges of their radioactive gaseous systems. At the request of the SZC Co., this option therefore looks at the possibility of doing likewise for relevant radioactive systems discharging via the HN stack. PIG monitors replace global beta channels when added at the same location.
- **Option n°2b:** Online “PIG” monitor + tritium/carbon-14 samplers: This option is an ‘improved’ configuration of option n°2 + the addition of tritium/carbon-14 samplers on relevant systems.
- **Option n°3a:** Offline Particulate/Iodine (PI) sampler to be analysed at the on-site laboratory, similar to the samplers adopted for the stack (See evidence 173). Noble gas activity trending is covered by the online gamma spectrometer on the TEG discharge line.
- **Option n°3b:** Offline PI sampler + tritium/carbon-14 samplers added to relevant system consistent with option 2b.

1021. The report concludes that while OEF shows that the arrangement of monitors and the procedures in place on the French fleet work, they do not allow comprehensive trending and quantification of all HN stack contributors as per the monitoring requirement. Options n°2 and n°3 both meet the monitoring requirement to various degrees. Option n°2 does not provide limits of detection comparable to stack monitoring techniques. Moreover, PIG monitors incur significant system/contract/layout impacts and cost. On this basis, these options are judged to present detriments that are disproportionate to the environmental benefits. Option n°3 involves an optimal number of monitors. The system design, cost, layout and contract impacts are considerably less than in Option n°2 and in the absolute terms remain minor to moderate, depending on which of the sub-options is retained. While the technical feasibility needs verifying, particularly for sampling on the TEG outlet, Option n°3b) meets the monitoring requirements with a proportionate amount of additional cost/system/contract/layout impacts compared to n°2b), and with only minimal cost and layout impacts compared to n°3a (due to the additional samplers). However, due to the variable flow rate on the TEG outlet (0-100 m^3/h), supplier feedback is required to determine the technical feasibility of a sampler allowing a representative sampling. This is captured as an open point on the open point register [OP 41] [Ref 174].

1022. Design change CGCA5015UK removed walls and ceilings in the rooms around the gaseous stack sampling devices. SZC Co. produced a paper on the options which is appended to the Environmental Ranking Form [Ref 166]. The walls being left in the design posed a potential risk to the demonstration of BAT in the selection of Gaseous Stack monitoring equipment due to the restriction of the space available. Additionally, ability to obtain a representative sample could be affected by retaining the walls due to increased length of pipework or additional bends required. As a result of the options assessment completed, the walls were removed.

b) Evidence 160: Provision for independent sampling of gaseous discharges

1023. The Environment Agency is likely to carry out regular inspections of nuclear sites to ensure compliance with the conditions of the permit and this may include taking samples for independent analysis. Means for independent sampling of discharges of gaseous effluent will be made available to the regulator. The independent sampling will be from the same locations as used by SZC Co. for self-monitoring of the plant and all data and quality control information will be made available to the regulator for inspection.

1024. All main unit vent stack sampling is backed-up by a redundant sampler of the same type (with the exception of the online gamma spectrometer, which is backed up by the 24hr sampler). The primary purpose of this equipment is to serve as a redundant sampler for discharge monitoring/accountancy purposes, however, all sampling equipment will be fitted with tamper-free seals to facilitate the taking of witnessed samples by the regulator. This meets the requirements as stipulated in Environment Agency internal guidance [Ref 168]. Manual validation of the flow rate and isokinetic requirements of the primary particulate probe can be undertaken via the maintenance hatches on the stack access platforms. Hatches will also allow for periodic manual flow rate monitoring to ensure the continuous flow meters are properly calibrated against a standard reference method, and allow suitable and safe access for maintenance of the flow monitors. Annual calibration against a standard reference method fulfils the ISO2889:2010 requirement for continuous flow measurement to be subjected to annual accuracy audits, currently an Open Point in the open point register [OP 182] [Ref 174] and HPC IC4.

c) Evidence 161: Sampling techniques for gaseous discharge monitoring

i. Tritium/Carbon 14

1025. The EOS1 report for gaseous discharge monitoring [Ref 169] determined the best practice approach for sampling of tritium and carbon-14 based on international recommendations (IAEA, EPRI, etc.) and OEF from the French fleet, and from Sizewell B, see Table 6-5.

Table 6-5 International Recommendations and OEF for Sampling Techniques

Radionuclides	International recommendations	France	Sizewell B
Tritium	Water chilled bubbler trains or molecular sieves	Water Chilled bubbler trains	Combined acidified water and sodium hydroxide bubbler train
Carbon 14	Sodium Hydroxide chilled bubbler trains or molecular sieves sampler	Sampled with molecular sieves	Combined acidified water and sodium hydroxide bubbler train

1026. For carbon-14 and tritium, either bubblers or molecular sieves are used. No important differences were identified between French and British practices. Whilst there are advantages/disadvantages or each approach, both provide the same level of performance in providing a representative sample.

1027. Advantages/Disadvantages of each of summarised in Table 6-6.

Table 6-6 Summary of Bubblers and Molecular Sieves

	Bubblers	Molecular Sieves

Advantages	Established UK practice for tritium and carbon-14 sampling. Established French fleet practice for tritium sampling. Simpler sample preparation for analysis by liquid scintillation counting. If only used for tritium sampling then the bubbler bottles contain water i.e. reduced handling hazard.	Established French fleet practice for carbon-14 sampling. Less sample handling hazards (passive sample media). Only one sampling line and one molecular sieve system required regardless of the need for speciation. Requires longer sampling frequencies so less sampling burden.
Disadvantages	Hazard from handling of glass bottles containing hazardous chemical solutions. If speciation is required, two sampling lines would be required and two sets of bubblers i.e. would require more space and additional sampling burden. Sampling frequencies are higher than for molecular sieves i.e. increased sampling burden.	Requires longer sampling frequencies so not really appropriate for tritium sampling in ventilation systems and in the HN stack. No UK OEF. No French OEF for tritium sampling. More complex sample preparation for analysis by liquid scintillation.
Notes	Bubblers and molecular sieve systems are of similar size.	

1028. Sampling frequencies for tritium will be in most cases higher than for carbon-14 therefore bubblers are more appropriate. Using bubblers for tritium sampling reduces sample handling hazards because the bubbler bottles are filled with water.

1029. Historically, carbon-14 sampling in the UK is undertaken at gas cooled reactors, which also require more frequent sampling and sampling of Sulphur-35 too. Carbon-14 discharges from a PWR as SZC are less subject to variations and replacement of sample media on a larger timescale - monthly basis is considered appropriate. Therefore, it was determined to sample by molecular sieves for carbon-14 as this reduces sample handling hazards and operator burden – especially given that use of molecular sieves requires no handling of hazardous chemicals by the operators.

1030. The report recommended that tritium is sampled via bubblers, whilst carbon-14 is sampled via molecular sieves and this has been adopted for SZC. The analytical method is similar regardless of the sample media, the only difference being the molecular sieves require additional sample preparation, but this is offset by the longer sampling period [Ref 169].

ii. Particulate/Iodine

1031. The EOS1 report for gaseous discharge monitoring [Ref 169] determined the best practice approach for sampling of particulates and iodine based on international recommendations (IAEA, EPRI, etc.) and OEF from the French fleet, and from Sizewell B, see Table 6-7.

Table 6-7 International Recommendations and OEF for Sampling Techniques

Radionuclides	International recommendations	France	Sizewell B

Particulates	Fine pore glass fibre filters	Fine pore glass fibre filters	Glass fibre filter collection and PIG monitor as a back-up technique
Iodine	Charcoal filters impregnated with potassium iodide and triethylnene diamine	2 set of charcoal canisters in series	1 charcoal canister integrated in the Maypack canister

1032. Given that the use of glass fibre filters for particulates, and charcoal filters for Iodine is consistent across international recommendations, including the French fleet and Sizewell B, then these will be adopted for SZC, and not considered further here.

1033. In order to ensure fully representative sampling a set of two cartridges in series will be used for Iodine. The second cartridge is used to demonstrate that the first cartridge is representative whereby no iodine has reached the second cartridge. Additionally, if the first cartridge is defective the second cartridge will capture and ensure the sampling of iodine. Analysis of the cartridges will be carried out within 24 hours after sampling.

iii. Noble gases

1034. The EOS report [Ref 169] examined International recommendations, and OEF in France and at Sizewell B, as summarised in Table 6-8.

Table 6-8 International Recommendations and OEF for Sampling Techniques

Radionuclides	International recommendations	France	Sizewell B
Noble Gases	On-line monitoring or grab sampling for specific effluent streams	On-line monitoring and grab sampling	Particulate Iodine and Gas monitors

1035. International recommendations suggested a combination of on-line monitoring and grab sampling. This is reflected in the SZC design. Online gamma spectrometry provides continuous indication of noble gas levels, with complementary sampling available via the 24hr sampler, which can be analysed in the on-site laboratory to allow a more detailed assessment of noble gas discharges to be produced on a periodic basis.

1036. Online monitoring extends to the use of beta detectors within the stack, which provide an immediate indication of elevated activity being discharged via the stack and allow automated actions to address the situation.

d) Evidence 162: Optimisation of the location of gaseous effluent discharge sampling points

1037. Discharge sampling equipment is located in dedicated sampling rooms on the top floor of the HN (primary and redundant monitoring equipment located in separate rooms on the top floor of the HN building). Following a detailed review of the floor plan, it was identified that the dividing walls used to isolate individual sampling and monitoring cabinets had the potential to limit the selection of equipment due to physical size, these were subsequently removed from the design via the design change process [Ref 166]. The removal of the walls ensured there was sufficient space for the equipment.

1038. An EOS1 report produced to optimise the height of the main unit vent stack [Ref 165] concluded that a stack height of 70m was optimal, and that increasing the stack height further would offer disproportionate environmental benefit compared to radiation protection, industrial safety and cost considerations. A further stack height assessment for SZC was completed that reached the same conclusions [Ref 160] and therefore all subsequent detailed design work undertaken for HPC is applicable to SZC.

i. Tritium/Carbon-14

1039. An optioneering report [Ref 169] was produced to examine alternate options for the arrangement of sampling lines on the stack. In the adopted option (see Figure 7 of [Ref 171]) the particulates and iodine monitor, tritium monitor and carbon-14 monitor are grouped on the same primary line since they are all samplers. BAT criteria was outlined in the EOS1 report on gaseous discharges [Ref 169] and is covered in detail in Appendix B of [Ref 171]. In summary the location will ensure that:

- sampling is carried out downstream of any abatement equipment;
- sampling points are located sufficiently high up in the stack that they sample a flow that is well-mixed and has a relatively uniform velocity profile; and,
- the sampling points take into account ISO2889:2010 guidance on their relative position in the stack i.e. (>5 Nominal Diameter (ND) from the bottom, and >3ND from the top of the stack). The lines start at a height of approximately 15-20m.

ii. Particulate/Iodine

1040. Given the potential deposition issues leading to a non-representative sample for the particulate sampler, it was determined that in the adopted sampling arrangement that the 100ND primary sampling line would be the first of the three on the main stack, and the particulate/iodine monitor would be located in the most optimised position (with regards to penetration factors) of the 3 monitors on that 100ND line, to minimise the length of pipework to the sampling equipment, and thereby minimise depositional losses.

1041. The particulate/iodine sampler is located on same primary line as tritium/carbon-14 sampler, so corresponding section for tritium/carbon-14 above applies in full.

iii. Noble Gases

1042. As isokinetic sampling is not required for monitoring of noble gases, and depositional losses are not a concern for their measurement, the two lines are above the ND 100 line in the stack. A slightly longer sampling line in this instance allows for the length of the particulate sampling line to be minimised, and by doing so reduce the potential for depositional losses. Stack flow modelling studies indicated that the flow will be sufficiently turbulent at each of the sampling lines for the gamma spectrometer/24hr sampler/beta monitors, and that criteria related to ISO2889:2010.

1043. A particular benefit of the adopted option for sampling lines in the stack was that it allowed a dedicated sampling line for the 24hr sampler, ensuring that its operation would not interfere with other samplers due to pressure drop during its operation.

1044. Diversified equipment on diversified lines was chosen to support the maintenance for the gamma spectrometer and the 24hr sampler.

e) Evidence 163: Isokinetic conditions for gaseous discharge sampling and monitoring

1045. For particulate discharge sampling, isokinetic conditions (where the velocity in the sampled duct is equal to the velocity in the sampling line) must be implemented to ensure the sample is representative. To ensure this the following criteria is applied:

- The sample probe must be oriented so that the probe opening faces the direction of flow or has a maximum offset of 20° to the direction flow.
- In order to improve the quality of the samples, the rate of sampling should match the rate of flow of effluent in the pipe.
- The probes should be designed such that they:
    - have a sharp (feathered) edge;
    - should be 0.8 - 1.3 for particles of 10 μ m;

  - should not be excessive (<15% of the cross sectional area of the duct; and,
  - have an inlet diameter not too small.

- For discharges, when the flowrate in the main duct/stack varies by more than 20%, the sampling rate should be matched in response (e.g. using a monitor with dynamic flowrate control).

i. Particulate/Iodine

1046. The design of the stack sampling arrangements is detailed in the SZC RSR Permit Head Document and are summarised below.

1047. The primary and secondary line feeding the particulates monitor is equipped with an isokinetic probe as required (ISO2889:2010).

1048. The primary sampling line is required to be 100ND to satisfy the minimum cross-section required for an isokinetic nozzle.

1049. The sizing of the probes is based on SZC expected flow rates in the stack to ensure isokinetic sampling. The justification for design of the stack sampling lines [Ref 182] will be supported by a future BAT assessment for the detailed design of the sampling nozzles.

1050. It will need to be confirmed that the higher flow rates expected in the SZC stack are compatible with certain ISO2889:2010 probe-specific requirements for isokinetic sampling (e.g. the exterior cone should not exceed an angle of 30°). These will need to be considered as part of detailed design of the sampling lines.

1051. It should be noted that isokinetic sampling is not relevant requirement for representative sampling of tritium, carbon-14 noble gases.

f) Evidence 164: Representative sampling techniques for gaseous discharges

i. Tritium/Carbon-14

1052. As with sample location, the BAT criteria is based largely on ISO2889:2010 and Technical Guidance Note (TGN) M11 [Ref 172] and was used to assess representativeness of the sampling location. The detailed design pertaining to the stack sampling techniques presented in this section is common across the HPC and SZC designs.

1053. To facilitate homogenization of the different streams that feed into the main unit vent stack and optimise representativeness, there is a plenum located at the base of the stack.

1054. It has also been confirmed a representative sample reaches the secondary sampling line. The flow is laminar in the secondary sampling line, which has significantly smaller diameter and minimises turbulent deposition. It should be noted that the turbulence of the flow in each of the sampling lines is factored into calculation of penetration rates, to take account of turbulent deposition when assessing representativeness of the particulate sampler.

1055. ISO2889:2010 includes recommendations for ensuring samples are extracted form a well-mixed air stream. Flow modelling was undertaken on the stack to ensure that the revised design of the stack sampling arrangements conformed with these recommendations. The flow modelling was undertaken for 3 different operational configurations (normal operations, cold shutdown and bounding case, between 331,000m^3/hr-400,000m^3/hr discharged via the stack) to demonstrate the samples would be representative. The requirement for commissioning tests to confirm the outcome of the flow modelling is captured in the open point register. The BAT assessment [Ref 182] demonstrates that the following ISO2889:2010 requirements must be taken into account when implementing the final stack sampling layout:

> *"The straight sections of transport tubes, particularly horizontal tubing sections, should be kept as short as possible, and the number of bends should be minimized within the geometrical constraints of the application. There should be no inward-facing steps at the tubing connections that cause more than a 1 % reduction in tube diameter. The tubing ends should be free of burrs and crimping. Bends should have a curvature ratio of at least 3. Flattening, which is defined as the ratio of the minimum tube diameter to the original tube diameter, should not be less than 0,85. The user should note that special fabrication techniques can be needed to meet these specifications".*

1056. Detailed models of the updated layout of the top floor of the HN building and stack have not yet been updated following the design change which adopted the new sampling lines arrangement in the stack, however the above considerations from ISO2889:2010 will be confirmed once this has taken place.

1057. Tritium present in stack effluent in the form of water vapour may condense in the KRT sampling lines under certain conditions. As sampling lines route down the inside the stack itself, sampled effluent and stack effluent will have similar temperatures, making condensation unlikely. In the comparatively short part of the sampling line that routes from the bottom of the stack to the monitor, it is possible that some condensation could occur however all sampling lines run inside rooms in a HVAC controlled building minimising this risk. The risk of condensation is also reduced by the use of the larger diameter (100ND) in the SZC design primary sampling line meaning there is proportionally less effluent in contact with the walls of the sampling lines. The need of trace heating for these lines is to be studied during performance studies for the stack sampling arrangements, and this is currently captured as an open point in the open point register [OP 192] [Ref 174].

1058. Representative sampling at the sampling point will be required to be demonstrated during commissioning using an appropriate tracer gas.

ii. Particulate/Iodine

1059. ISO2889:2010 recommends no longer using a nozzle of constant internal cross section due to substantial aerosol particle losses in the straight entrance region. Use of a nozzle with increasing internal cross-section minimises particle losses. The SZC design involves a probe of initial diameter of 54ND (required for isokinetic sampling) which increases to 100ND. Likely particle sizes measured in the stack will be significantly smaller than 10 µm, given the HEPA filtration upstream. To qualify as HEPA by industry standards [Ref 173], an air filter must remove (from the air that passes through) 99.97% of particles that have a size greater-than-or-equal-to 0.3 µm. SZC HVAC design utilises inlet filters to minimise particulate load entering the HVAC system and pre-filters are used to maximise the life of the HEPA filters by protecting them from larger particles.

1060. The stack sampling optioneering study [Ref 165] took into account the following points to optimise the design:

- The HN sampling rooms are immediately adjacent to the plenum of the stack in order to minimise sampling line lengths. In order to minimise the distance further, it would not be possible to have a dedicated sampling room, which could potentially compromise the requirements for suitable and safe access to the equipment.
- It will be ensured that the iodine/particulate sampler will be located on the most optimum secondary sampling line. This will not necessarily be the shortest total line length, rather the most optimum balance between overall line length, and secondary sampling line length. Ideally, overall sample line length and secondary sampling line length will be minimised as far as is reasonably practicable, but in particular minimised secondary sampling line length will be preferred given the increased likelihood of deposition on the smaller diameter line.
- The ND 100 line is the first of the three in the stack (from the bottom), again to minimise sample line length.
- Measured results from the particulate sampler are used primarily for discharge accounting and reporting of discharges to the EA. The particulate sampler is not the method via which HEPA

filtration failure will be determined and is not considered as an instrument used to initiate operator actions in response to elevated discharges. HEPA filtration performance is monitored via differential pressure across the filter itself.

- A significant design change has taken place in order to optimise the design compared to the existing FA3 design, resulting in a significant improvement in representative sampling with regards to particle penetration. The option adopted was informed by sampling arrangement recommended by ISO 2889:2010; whilst the option adopted differs from the ISO 2889:2010 design, it does not do so in any way which will affect penetration rates.
- As per the stack contract technical specification [Ref 177]; the interior surface of the stacks shall be smooth with low roughness, including no joins between sections, to minimise the deposition or impingement of particulates carried in the exhaust.
- Well-designed sampling lines are key for ensuring penetration rates are optimised, and the number of bends and lengths of horizontal sections shall be minimised as far as is reasonably practicable in the detailed design of the secondary sampling lines. It is noted that as it runs down the side of the stack, the majority of the length of the primary sampling line will be vertical, which minimises gravitational settling, resulting in a higher penetration factor.

1061. The stack sampling optioneering study showed that significant improvement in the penetration rates as a result of the change to the design of the sampling line, however given the recommendation of the ISO standard is not met, it must be confirmed that the current design represents BAT, and that all meaningful alternatives have been considered. These alternatives are considered in the context of the potential impact of discharges of gaseous particulate matter at the permitted limits to the environment; noting that this presents a pessimistic estimate of the dose a representative member of the public would actually receive. The dose to the SZC representative person arising from discharges of radionuclides associated with particulate in gaseous effluents at SZC is calculated at 0.002µSv yr^{-1} [Ref 10].

1062. Further means to increase penetration rates were investigated, including moving the sampling equipment closer to the stack and placing the sampling nozzles lower down the stack however it was concluded that the alternative options did not provide any significant improvement without significant dis-benefits that would outweigh any potential improvement in penetration factor (though the reduction of vertical primary sample line length). Therefore, there is no further design change that would constitute BAT, and the alternative options to the current design are ruled out. The current design will be retained and there will be no further design change to the stack sampling arrangements.

1063. Where relevant and available, FA3 OEF will be reviewed to assess whether the 3D modelling originally undertaken was overly conservative. Any pessimisms that can be reduced in the 3D modelling will be considered and undertaken where there is sufficient underpinning evidence to support such action. This is captured as an open point on the Open point register ensure at commissioning it is confirmed whether this requirement is met [OP 182] [Ref 174]. For the SZC project, relevant commissioning OEF from FA3 (where available) and HPC, will be used to confirm whether this requirement is likely to be met for SZC. On acceptance of the report to close out HPC IC4 of the HPC RSR permit, the Environment Agency RASCAR included an action for NNB GenCo (HPC) notify the Environment Agency by letter if commissioning data confirms that any ISO2889 requirement will not be met.

1064. It is recognised that ensuring overall particulate (as well as particle size) in the effluent is minimised is dependent on good operational controls (training and competence in fitting and replacing HEPA, adequate instrumentation to detect pressure changes, maintenance regimes to change filters appropriately and their testing to ensure correct fitting etc.) to minimise the risk of bypass, leakage and damage that would result in larger particles could enter the sampling system.

1065. Tritium present in the HN stack discharge in the form of water vapour and may condense in the KRT sampling lines under certain conditions. This could then have a knock-on effect on particulate deposition, as aerosols are soluble and may dissolve into the condensed water. Iodine solubility depends on its form, iodine in its elemental form has a very low solubility whereas iodide is soluble. The requirement for condensation risk of iodine to be taken into account is captured as an open point [OP 42] [Ref 174].

i. Noble Gases

1066. Given that the Beta monitors/Gamma Spectrometer/24hr sampler are located on the DN 15 sampling lines which feed directly into the stack, the evidence that demonstrates that the flow within the main stack is sufficiently well-mixed (see Tritium/carbon-14 section above on homogenisation) applies. Concerns associated with secondary sampling lines do not apply.

Equipment specific requirements

1067. Length of pipe between the probe and the sample collection/on-line monitor should be short enough so that detection time does not impede their functional role. This means that it is important to consider if the half-life of the radionuclides being monitored is compatible with the time taken for sampled effluent to reach the monitor. This applies notably to the beta gas monitors and gamma spectrometer, which supply noble gas activity concentration measurements in real time (other monitors contain filters/cartridges/vials which are changed periodically). Based on the normal flowrate of these monitors (35L/h), transit time should be of the order of approximately 10-15s. Reference radionuclides for online measurement are chosen to provide the best indication of noble gas activity, and thus the measurement will be based on radionuclides with sufficiently long half-lives so as to make the detection time negligible. The total noble gas discharges reported will be estimated for short-lived radionuclides based on the activities of the reference radionuclides measured.

1068. For the beta gas monitors and gamma spectrometer the rate at which the effluent entering the monitor is renewed is not considered to significantly impact representativeness for either the FA3 design or SZC options.

1069. There are no specific requirements for representativeness associated with the 24hr sampler in addition to those above.

g) Evidence 165: Operation and maintenance of the gaseous effluent sampling system

1070. The detailed layout of piping and equipment will ensure suitable and safe access by following the Engineering rules for design and layout of piping and fittings [Ref 175] which requires a standard space of 2.2m between floors and overhead pipes and 0.9m minimum width for main movement areas and 0.6m for areas with little personnel traffic and around equipment on three sides. In addition, SZC operates a Human Factors (HF) programme for civil works and layout. The main objective of the HF approach is to ensure safe access to local plant, workstations and equipment layouts and ease of use, and considers ambient conditions such as temperature, noise, lighting, radiation protection and signage, as defined in [Ref 176]. These factors will be considered as part of the building review process to validate the safe access for operator sampling and maintenance activities, and when required Environment Agency sampling during future design states.

1071. Further detail for the specific equipment is provided below:

i. Sampling lines & probes

1072. The stack contract technical specification [Ref 177] sets out the stack design requirements to facilitate suitable and safe access for the sampling/monitoring equipment:

- The design shall ensure safe and permanent means of access to each of the locations where measurement equipment, inspection and testing elements are installed.
- A 360° platform is set up just below the top of the stack, at the measurement flow rate level, and at the intermediate flanges. The platforms shall be long enough to allow access to the

measurement KRT level. The platforms shall be sufficiently large (both in width and length) to ensure the ability to safely work at height, including but not limited to installation, removal and testing of probes and equipment including at the KRT levels. The upper platform is located high enough between the platform level and the top of chimney to allow maintenance activities. Each platform is supplied with guard-rails, as defined according to the standard BS EN 14122-3.

- Flow rate measurement sensors and temperature sensors are set up halfway up the stack. Inspections and maintenance of the instrumentation are undertaken via 4 hatches built into the stack structure that have a minimum diameter of 500mm. A seal between the flanges is required to ensure the air tightness of the hatch to mitigate any emissions.

1073. 3D model images showing the access ports for the sampling probes, and the flow meters are in Appendix E Figure 1 & 2 of [Ref 171].

1074. Each dedicated gaseous sampling room is sufficiently large; the smallest floor space is 25m^2 to allow for personnel and equipment access for maintenance operations on the sampling equipment. Sampling Rooms are accessible via lifts in the HN building, or via stairs. Personnel will not be required to climb any ladders to reach the sampling rooms.

ii. Sampling equipment

1075. The sampling rooms are equipped with appropriate facilities and services (HVAC, lighting, electricity etc.). In particular, the rooms are equipped with connections to the SAT, for cleaning sampling lines prior to maintenance operations.

1076. Each dedicated sampling room has sufficient floor space (the smallest is 25m^2) to allow for personnel and equipment access for operations and maintenance activities on the sampling equipment. The removal of the dividing walls in the HN sampling rooms [Ref 166] serves the dual purpose of allowing more room for the equipment itself, and facilitating additional space and access for maintenance operations.

h) Evidence 166: Design of the gaseous effluent sampling line

1077. The following design features/criteria optimise the design of the sampling line:

- The secondary sampling line piping has a ND of 15mm and the start of each sampling line is equipped with a probe.
- Sampling pipes are made from stainless steel 304L, which is inert and corrosion resistant. Department of Energy standard on tritium handling and safe storage [Ref 178] recommends 304L or 316L stainless steel. Low carbon grade stainless steel like 304L has fewer impurities, resulting in less hydrogen-induced cracking, whilst maintaining good strength and weldability.
- RCC-M codes adopted for effluent adjacent pipework on the SZC project requires internal roughness of internal pipework to be minimised as much as is reasonably practicable.
- Iodine/particulate samplers are equipped with a dynamic flowrate control. This allows automatic compensation of flowrate variations at the stack and ensures isokinetic conditions are maintained throughout sampling.
- The gamma spectrometer is equipped with a pressure measurement, which is used to compensate density variations in the sampled effluent and provide more accurate volumetric activity measurement (at standard atmospheric pressure). Filters at the inlet of the devices prevent dust from entering the measurement chambers. Each chamber is surrounded by lead shielding to reduce background radiation reaching the detector thus improving the performance of the measurement. Monitors are located in a low background radiation zone so as to minimise

any interference with the on-line measurements. Where necessary, additional shielding will be incorporated in the design of the monitors.

i) Evidence 167: Optimisation of temperature, pressure and flow-rate conditioning for the gaseous effluent sampling and monitoring system

1078. Samples are conditioned in term of temperature, pressure, flowrate as appropriate via one and/or two stages of conditioning (primary and/or secondary conditioning). The efficiency of the conditioning is monitored to ensure samples parameters are as expected (e.g. conditions required at the inlet of the online measurement devices to ensure representativeness of the measurements).

1079. Where required monitoring devices will be equipped with a flowrate sensor and a pump, ensuring that sampled effluent is representative and suitable for analysis. If conditions vary outside of acceptable operating parameters, the device automatically takes itself offline and an unavailability alarm will be triggered.

1080. Gross beta monitors and the gamma spectrometer will be equipped with a pressure measurement, which is used to compensate density variations in the sampled effluent and provide an accurate volumetric activity measurement (at standard atmospheric pressure). Filters will be fitted at the inlet of the devices to prevent dust from entering the measurement chambers. Each chamber will be surrounded by lead shielding (and potentially copper liners) to reduce background radiation reaching the detector, thus improving the performance of the measurement. Monitors will be located in a low background radiation zone so as to not interfere with the on-line measurements. Additional shielding can be incorporated into the design of the monitors, where necessary.

j) Evidence 168: Optimisation of alarms, automated actions and back-ups for gaseous effluents

1081. In the event that the activity concentration detected by the global beta channels exceeds pre-set values, alarms sound in the 24 hour manned Main Control Room (MCR). In the event that a tritium, carbon-14 or particulate/Iodine sampler becomes unavailable, a grouped unavailability alarm sounds in the MCR. Other samplers have their own specific unavailability alarm.

1082. Redundant sampling lines are in place for all sampling equipment with a separate dedicated room in the HN building housing the equipment. These are connected to electrical supplies that are backed up by diesel generators.

k) Evidence 169: Radiological protection for operators for gaseous effluent sampling and monitoring

1083. Minimisation of sampling line length needs to be balanced against radiation protection of workers and safe and easy access to the sampling equipment. The provision of dedicated sampling rooms within the HN building provides significant radiological protection to the operator than if the sampling equipment was located significantly closer to the stack. This allows the sampling equipment to be located in a green radiological protection zone at the expense of a slightly longer sampling line.

1084. The walls removed [Ref 166] from the HN sampling rooms were designed to serve a shielding function for the equipment, but it was determined that shielding could be included on the equipment itself, if necessary, and the removal of the walls would not pose an increased risk to workers.

l) Evidence 170: Protection of the gaseous effluent sampling equipment

1085. The sampling lines and sampling equipment are located inside the HN building, thus protecting them from extreme temperature conditions and certain external hazards. The dedicated sampling room is ventilated by the HN building ventilation systems to ensure adequate ambient conditions for the monitoring equipment.

1086. The sampling equipment is located within the RCA, which will prevent access by unauthorized personnel, with sampling cabinets fitted with locks. Tamper-evident seals will be fitted to equipment to facilitate witnessed sampling.

6.5.3 Sub-Argument 28: Appropriate in-process monitoring is undertaken and optimised for gaseous effluents

1087. The requirement for consideration of in-process monitoring as part of the site radioactive effluent sampling, measurement and assessment programme is stated in Environment Agency guidance.

1088. In-process monitoring is required to determine the composition of radioactive substances in primary coolant, process fluids, reactor off-gas and associated effluent for plant operations. The monitoring data may identify trends of activity in radioactive effluent that may indicate a chronic plant or process problem. It is important for ensuring that the treatment of process fluid and effluent abatement plant are performing adequately, thereby minimising discharges and allowing corrective actions to be taken by the operator if radioactivity levels are unexpectedly above specific thresholds.

1089. The in-process monitoring techniques involving sampling and measurement are normally the same or equivalent to those used for discharge sampling and measurement, further described in RSR Permit Application Support Document C1 [Ref 6].

1090. SZC Co. has considered guidance, best practice and OEF worldwide in order to identify the best practice when it comes to sampling technique.

1091. As part of the EOS1 studies [Ref 179] [Ref 180] [Ref 181] [Ref 169] to determine that the sampling arrangements were BAT, BAT assessment criteria were jointly defined by NNB GenCo (HPC) and RD throughout workshops. These criteria and the conclusions reached in the EOS1 report were reviewed in 2018 as part of NNB GenCo (HPC) work to contribute to closure of HPC IC4 of the HPC RSR permit, and given the sampling arrangements are retained for the SZC design, they are considered appropriate for the SZC project.

1092. The criteria are based on the relevant standards, regulatory guidance and best practice:

- Environment Agency guidance, in particular Technical Guidance Note M11 [Ref 172];
- relevant national and international standards and expert studies and recommendations (ISO, French standards, EPRI recommendations);
- relevant EDF standards; and,
- EDF PWR fleet OEF and best practice.

1093. The BAT assessment criteria have been grouped in five categories:

- Location of the sampling point (contributing to representativeness of sampling/on-line measurements).
- Isokinetics (also contributing to representativeness of sampling/on-line measurements).
- Representativeness (other than location and isokinetics).
- Operation and maintenance.
- Other principles (any other applicable recommendations, including civil work constraints).

1094. They are established to ensure that the design of sampling and monitoring systems adequately delivers the monitoring strategy and enables representative sampling. They also ensure that there is sufficient space for sampling and monitoring equipment, suitable sampling arrangements, suitable and safe access to sampling and monitoring equipment and suitable environmental conditions.

a) Evidence 171: Arrangements for in-process monitoring of gaseous effluents

1095. In-process monitoring equipment is used to measure airborne concentrations of radioactivity in specific buildings so that iodine adsorption filters can be deployed to minimise environmental discharges, if required. In addition to the monitoring/sampling implemented on the stack, monitoring of global beta activity is implemented on each cell of the DWN, DWQ and EBA low flow, to monitor their contribution to discharge in the HN stack. Noble gas detection is taken as a precursor to iodine release, and high activity detected on these channels will result in automatic switchover to iodine filtration for the cell in question.

1096. A BAT assessment [Ref 161] was produced to examine options for additional in-process monitoring on systems that contribute to HN stack discharges. The objectives of this optioneering are to:

- Provide a comprehensive and argued analysis of all the possible design options for the quantification of different buildings’ contribution to gaseous radioactive discharges at the HN stack.
- Provide a record of the different arguments aiding the decision making process, in order to comply with UK requirements, notably the application of BAT principles.
- Make recommendations about the most suitable option(s).

1097. The following additional sampling locations that were proposed:

- Fixed equipment for carbon-14 monitoring in the air coming from EBA high flow (DWN ventilation cell 7). C-14 samplers have been added onto any lines from systems in contact with the primary coolant (i.e. EBA high-flow, EBA low-flow and TEG).
- Fixed equipment for tritium monitoring in the air coming from the Fuel building (DWN ventilation cell 5). The fuel pool is served only by the part of DWN that feeds into cell 5 on DWN. The sampler is therefore needed only on the cell 5.
- Fixed equipment for carbon-14 monitoring on the discharge line of the EBA low flow system. C-14 samplers have been added onto any lines from systems in contact with the primary coolant (i.e. EBA high-flow, EBA low-flow and TEG).
- Mobile equipment for tritium and carbon-14 monitoring upstream of HEPA filter banks (TES cell) sampling during sludge and evaporator concentrates encapsulation/Mercure campaigns
- Fixed equipment for PI monitoring on DWQ downstream of HEPA filter and Iodine trap located in order to exclude DWQ in case of high activity due to particulate and iodine discharges at the stack, a particulate/iodine sampler has been added to the DWQ discharge line.
- Mobile equipment for carbon-14 and tritium monitoring on the TEG discharge line (downstream of all charcoal delay beds) located in HNX2035ZL. The tritium sampler is to monitor potential water ingress into the TEG’s carbon delay beds. C-14 samplers have been added onto any lines from systems in contact with the primary coolant (i.e. EBA high-flow, EBA low-flow and TEG).
- Fixed equipment for particulate/iodine monitoring on the TEG discharge line (downstream of all charcoal delay beds).
- It was determined that adding PI samplers upstream of HEPA filtration/Iodine abatement on each of the inlets to DWN is disproportionate to the operator burden incurred by additional sampling and analysis activities, and would not be representative of the activity discharged post-filtration. The cells 1 to 7 feeding to DWN all merge into a plenum downstream of treatment so it is not possible to sample individual cells downstream of treatment. As a result, only one PI sampler was added on the DWN discharge line (after all 7 cells have merged) but before the stack plenum.

Accountancy for each of the individual cells is expected to come from the existing beta activity monitoring devices upstream of the abatement equipment from each line.

1098. The above additional monitoring arrangements were implemented to the design via design change CCSE5070UK [Ref 182].

1099. A BAT assessment [Ref 183] provides the BAT/ALARP analysis for tritium/carbon-14 sampling of the TEG recombiner for SZC, which concluded that provision for mobile sampling of tritium/carbon-14 would utilise existing sampling cabinets for hydrogen/oxygen measurement. This will allow periodic monitoring of H3/C14 activities upstream and downstream of the recombiner, to enable the operator to better understand the impact the recombiner has on speciation of H-3/C-14 into liquid/gaseous phases.

1100. A BAT assessment [Ref 184] provides the BAT/ALARP optioneering report of the TEP6 degasser performance (decontamination factor (DF)) monitoring, which concluded that the assessment of TEP6 degasser will be based on liquid effluent sampling alone, as whilst the design enables sampling of the gaseous phase of TEP6, activity measured in gas samples via gamma spectrometry would not necessarily be representative and would not be a good measure of degasser efficiency. Gas chromatography will be used to monitor levels of H_2 and O_2 in the gaseous phase.

1101. A number of EOS [Ref 179] [Ref 161] [Ref 185] detail how in-process monitoring is required for the sampling and measurement of gaseous effluents in up-stream locations on HVAC systems routed to the main discharge outlets, in response to events or for investigation purposes. This will be achieved by the use of fixed and mobile sampling equipment to allow the operator to provide feedback on the contributions of various processes/systems to the final stack; these samples will not be used for final discharge reporting.

1102. The location of the sampling points in the gaseous effluent process systems is important to ensure representative sampling is achieved. Sampling, measurement and assessment of radioactivity in reactor-off-gas using in-process monitoring is required to sanction its discharge into reactor-specific main discharge outlets from the charcoal delay beds and tanks.

b) Evidence 172: Monitoring techniques used for in-process gaseous effluents

1103. The EOS1 report for gaseous discharge monitoring [Ref 169] determined the best practice approach for sampling of tritium and carbon-14 based on international recommendations (IAEA, EPRI, etc.) and OEF from the French fleet, and from Sizewell B. Techniques for particulates, Iodines and noble gases were also confirmed based on international OEF. These conclusions are presented in evidence 173, and are also considered appropriate for in-process monitoring.

1104. In addition, a number of other techniques are used for specific monitoring requirements:

- The Main Steam System (VVP) transfers steam from the outlet of each of the SG in the HR, through the HL’s and towards the turbine in the Turbine Hall via the system VPU. The KRT monitoring devices on VVP are each composed of two processing channels (or processing “modes”) as follows [Ref 186]:
    - The first processing channel (the “high energy” (16N) processing mode) is used to measure the primary to secondary leak rate when the reactor is at or above ≥20% of nominal reactor power.
    - The second processing channel (“low energy” (135Xe, 138Xe, 85Kr, 87Kr, 88Kr global gamma) processing mode) that informs the operator of activity in the VVP lines independent of the reactor power, so it is used to detect SGTRs in all plant states (when the SGs are in use).
- In order to carry out periodical tests on delay bed performance, manual sampling lines are

located upstream and downstream of bed 1, and downstream of bed 3. These gas samples will be analysed by spectrometry in the on-site laboratory. The delay bed sampling lines have a simple ‘T-junction’ connection and do not protrude into the process pipe. As indicated in [Ref 172], probe design is not critical for vapours and gases as long as the diameter of the probe is appropriate for the flow rate of the effluent sampled, and that there is good mixing at the sampling point.

- There is a monitoring provision on the CVI to detect the presence of non-condensable noble gases in the secondary circuit, indicating a primary to secondary leak. CVI is monitored via an external detection channel.

c) Evidence 173: Optimisation of the location of gaseous effluent in-process sampling points

1105. The location of the sampling points has been chosen with respect to international best practices and in compliance with UK standards:

- Each sampling point is placed in a zone where the flow is strongly turbulent and far enough from any disturbance, thus ensuring homogeneity at the sampling location:
    - Nearest upstream flow disturbance ≥ 5-10 HD
    - Nearest downstream flow disturbance ≥ 3 HD
    - Avoid placing the sampling point near dead legs/ends or low points.
    - Ensure a turbulent flow at the sampling point. (Reynolds number ≥ 4000)
    - Ensure that if any interfering effluent arrives before the sampling location, that distances downstream of the merged flow must be respected as above.
- The sampling line protrudes into the sampled pipe as appropriate (should protrude into the central section and pointing upstream).
- Sampling point to be as close as possible to the component to sample.

1106. A full analysis of all in-process sampling and monitoring was undertaken against these criteria in [Ref 179] [Ref 185], to ensure they are applied as far as it reasonable practicable (though some criteria are only applicable for certain monitors).

d) Evidence 174: Isokinetic conditions for gaseous in-process sampling

1107. The criteria for isokinetic sampling of gaseous in-process monitoring is the same as that set out in [Evidence 162] for discharge sampling.

1108. For in-process monitoring, isokinetic requirements apply only for two sampling points:

- The sampling point for particulates and iodine on the outlet of the 9DWQ.
- The sampling point for (iodine/particulates, noble gases, tritium) upstream of HEPA filtration in EBA low-flow.

1109. Where iodine sampling is implemented without particulates, such as the one on the discharge line of TEG, this does not require isokinetic sampling.

1110. For 9DWQ Isokinetic requirements have been applied to ensure sample representativeness:

- The sample will be taken in the middle of the duct (protrusion of about 1/3 of duct ND).
- The sampling probe will face flow direction.

1111. It was proposed during the meeting between NNB GenCo (HPC) and the RD that the disturbance could be minimised by increasing the bend radius and that supplier feedback is needed to assess the improvement provided by the change of bend radius and to determine the optimal radius enabling isokinetic sampling. 3D flow modelling validated the position of the PI unit through UK4901 supplier studies. The issue was closed via design change CCSE5070UK reviewed [Ref 170] and supported by the BAT assessment of the height and spacing of KRT sampling lines at the HN stack [Ref 182].

1112. The EBA low-flow sampling line is provided with an isokinetic probe for the PI sampler, for ensuring representativeness of the sample. Internal roughness is to be below 1.6µm.

1113. For all isokinetic samplers, the Nozzle transmission ratio, frontal area and nozzle edge will be designed and evaluated by the chosen supplier to meet the requirement.

e) Evidence 175: Representative sampling techniques for gaseous in-process effluent

1114. Representativeness requirements have also been taken into account and integrated in the design as recommended by international experts (EPRI, International Association for the Properties of Water and Steam (IAPWS)) and in compliance with UK/EDF standards:

- A turbulent flow is ensured in almost all the sampling lines (Reynolds number higher than 4,000. Where the flow is laminar in the sampling line, number of bends, low points, dead ends/legs and length of the sampling line are minimised).
- The number of dead legs/ends, low points and bends are minimized as far as reasonably achievable taking into account civil constraints. The unavoidable bends (due to layout constraints) are gradual, thereby limiting the risk of deposition.
- Deposition has been minimized notably through:
  - Velocity should be a minimum of 0.5m/s.
  - Minimization of the number of bends in the sampling line, and use of large radius bends, ideally ≥ 5 times the pipe diameter.
  - Limited in number.
  - Ensuring a turbulent flow in almost all the sampling lines.
  - Minimisation, as far as reasonably practicable, of sampling line length.
- The length of sampling lines is mainly due to the location of the sampling equipment (to ensure they are located in green or light yellow RCA where practicable to ensure safe and suitable access and reduce doses to the operator.
- The sampling pipes and equipment are made of austenitic stainless steel recommended for use in nuclear industry as being inert and corrosion resistant, with internal surface roughness Ra ≤ 12.5µm for mechanically classified systems, and ≤ 1.6µm for particulate sampling.
- Where needed, low flowrate and equipment failure alarms are provided in the I&C.
- In general, sampling lines for gaseous effluent are relatively short (between 2.4 and 18m). The equipment (valves, filters, etc.) installed on the sampling lines upstream of the sample

collector/on-line measurement device are limited to the strict minimum. Those that are present are needed to ensure appropriate conditioning of the samples and for maintenance needs.

1115. A full analysis of all in-process sampling and monitoring was undertaken against these criteria in [Ref 179] [Ref 185], to ensure they are applied as far as it reasonable practicable.

f) Evidence 176: Operation & Maintenance of gaseous in-process monitoring

1116. The requirements related to operation and maintenance needs of the in-process monitoring provisions have also been taken into account:

- Sample collectors/on-line measurements are located in appropriate areas with regards to radiological protection of workers (ideally in green or yellow RCA’s where possible).
- These location choices for the sample collectors/on-line measurements facilitate their safe access both for operation and maintenance needs:
    - Sufficient space around samplers/monitors is provided to easily undertake sampling and maintenance activities.

    - Easy access to room via corridors, and no need use stairs to transport mobile sampling equipment.

- The rooms housing sample collectors/on-line measurements are appropriately ventilated to ensure adequate ambient conditions for the operator and equipment.
- The rooms housing sample collectors/on-line measurements are provided with all appropriate facilities and services, such as SAT compressed air, gas, electricity, lighting, etc. This facilitates operation and maintenance activities.
- Sounding/display of an alarm in the event of equipment failure, and appropriate automatic actions. To make operation easier, certain alarms are provided locally as well as at the entrance to the RCA and in the main control room as appropriate.
- Back-up provisions are available, where high reliability of the sampling system is required, for instance for the VVP leak detection monitors.

1117. As for the previous BAT criteria, a full analysis of all in-process sampling and monitoring was undertaken against these criteria in [Ref 179] [Ref 185], to ensure they are applied as far as it is reasonably practicable.

g) Evidence 177: Other requirements for gaseous in-process monitoring

1118. Other principles have also been taken into account as recommended by international best practices and in compliance with UK standards:

- In order to minimise radioactive waste, samples are recycled back to the sampled system;
- The location choices for the sample collectors/on-line measurements (green/yellow areas) ensure operator radiation exposures are ALARP. Appropriate protection of equipment from adverse environmental conditions and unauthorised personnel entry is in place:
    - Access to the HN is controlled (within RCA).

    - Access to the non-RCA part of the HL’s and to the Turbine Hall (HM) is controlled.

    - For KRT channels, the access, or modification of alarm thresholds and internal parameters of these channel are under supervisor responsibility who does not allow permission for unauthorised personnel. Software lock - out or equipment exist to prevent access for unauthorised personnel.

    - Appropriate ambient conditions for equipment are ensured (appropriate ventilation sizing etc.).

h) Evidence 178: Analysis and assessment of radioactive gaseous effluents

1119. Analysis of radioactive gaseous discharge samples will provide representative measurements of the radioactivity discharged to the atmosphere.

1120. Two types of analysis will be undertaken:

- laboratory analysis of samples taken from the each of the HN stacks; and,
- on-line measurements where appropriate.

1121. The stack samples will be collected periodically and analysed for at least the radionuclides and group of radionuclides that are subject to discharge limits in the SZC RSR permit. The analysis will be undertaken in the HN laboratory.

1122. The analytical equipment selected will provide representative results with appropriate limits of detection taking account of the European Commission’s recommendations, international best practice and relevant standards, in particular:

- BS EN IEC 60761 (2002-01) – Equipment for continuously monitoring radioactivity in gaseous effluents;
- IEC 62302 (2007-01) – Radiation protection instrumentation – Equipment for sampling and monitoring radioactive noble gases;
- BS EN ISO 17025 – General requirements for the competence of testing and calibration laboratories;
- BS ISO 11929:2010 – Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurement of ionising radiation – fundamentals and application; and,
- KTA 1503.1 - Monitoring and Assessing the Discharge of Radioactive Substances with Water

1123. The discharge flow-rate will be measured continuously and representatively in each of the main stacks (HN).

1124. The activity discharged will be assessed using the following method:

- The activity measured for each radionuclide or group of radionuclides will be expressed in Bq/m^3 or Bq/l:
    - If the measurement is above the limit of detection of the analytical instrument used, the actual measured value will be used.
    - If a radionuclide or group of radionuclides is measured at the limit of detection, the activity in the sample is considered as half the limit of detection unless it can be demonstrated that the radionuclide or group of radionuclide measured cannot have been present in the discharge outlet in which case the activity is considered as null.

- The activity in Bq/m^3 or Bq/l is then multiplied to the volume of effluent discharged over the sampling period to obtain the activity discharged over the sampling period.
- Each time a stack is sampled the activity discharged is added to the site rolling totals over 3 months and 12 months so they can be compared against the QNLs and annual limits, respectively.

6.5.4 Claim 5, Argument 25: Aqueous Effluent Monitoring

1125. Aqueous discharges from the main discharge outlets at SZC will be sampled representatively to allow assessment and reporting of discharges, and to check compliance with the discharge limits and QNLs specified in the RSR permit. Where monitoring is required in order to demonstrate compliance with the RSR permit, suitable redundancy is provided in the event of equipment failure.

1126. In-process monitoring is aimed at providing information to demonstrate that the operations giving rise to radioactive effluent and the use of abatement plant and all associated control and management systems are performing as planned. Monitoring results will be used to optimise the operation of the plants where radioactive liquid effluents are produced and in their associated abatement plants.

6.5.5 Sub-Arguments 29: Sampling and monitoring of radioactive aqueous discharges

1127. The design of sampling lines for radioactive aqueous discharges is underpinned by the following features:

- Monitoring of appropriate radionuclides, at an appropriate frequency.
- Consistency with international best practice.
- Compliance with relevant MCERTS standards or equivalent, where applicable.
- Consistency with relevant national and international standards.
- Consistency with regulatory and industry guidance and codes of practice.
- Appropriate location of sampling points, in particular:
    - sampling point to be preferentially placed in a zone where the flow is strongly turbulent to facilitate good mixing, but far enough from any point that could disturb the flow or where interfering effluent may arrive (if this cannot be achieved these conditions will have to created artificially, e.g. using baffles or spillways);
    - sampling point to be preferentially placed with an immersion at least equal to a third of the pipe hydraulic diameter and far enough from the pipe wall;
    - sampling point to be as close as possible to the component to sample; and,
    - sampling point to be downstream of any abatement plant but upstream of any point where further dilution of the waste stream occurs.
- Appropriate design of the sampling system to ensure representative sampling, in particular:
    - sampling probe ideally to be pointing upstream, preferably at an angle of 180° to the direction of flow;
    - the flow in the sampling line should ideally be turbulent;

  - deposition rate, condensation and plate-out effects have to be ALARP (notably sufficient velocity in the sampling pipe and trace-heated pipe);
  - use of inert and corrosion resistant materials (ideally stainless steel);
  - minimisation of the length of pipe between the probe and the sample collector/on-line monitor;
  - minimisation of bends in the sampling line. If bends cannot be avoided, they must be gradual;
  - location of valves and other equipment such as pumps to be downstream of the sample collector/on-line monitor and prevent bypass of the sample collector/on-line monitor during sampling or on-line measurement;
  - sampling carried out well away from any ductwork features such as dampers, bends and merged streams, which may have a detrimental effect on mixing and flow patterns. Alternatively, demonstration of a well-mixed flow at the plane where the sample is taken;
  - minimisation of internal roughness on sampling pipe walls as far as reasonably practicable;
  - prevention of particulate matter deposition downstream and/or carrying over to the analysis stage, by use of a particulate filter in sampling probe; and,
  - testing using appropriate tracer or comparing results of analysis of samples taken at different points to demonstrate representativeness. Results of tests must be in the range of values specified in the norms.

- Appropriate consideration of operational and maintenance requirements, in particular:
  - back up is provided for the essential components of the sampling system (e.g. pumps) where high reliability of the sampling system is required;
  - there is safe and easy access to sample collectors/on-line measurement devices for maintenance activities;
  - appropriate facilities and services are provided to the sampling/on-line measurement system for routine and maintenance operations (e.g. electricity, lighting and water);
  - there is sufficient space for maintenance equipment and personnel;
  - sampling collector locations to be safely and easily accessible for operational activities; and,
  - sounding/display of an alarm in case of equipment failure or authorized limits being exceeded and appropriate automatic actions.
- Consideration of civil work constraints.
- Consideration of operator radiation protection e.g. valves with « remote » command, use of gloveboxes, appropriate shielding etc.

- Appropriate disposal/recycling of samples.
- Appropriate temperature, pressure and flow-rate conditioning of the effluent in the sampling line.
- Protection of equipment from environmental conditions and people interference where needed (e.g. sampling/on-line equipment placed in locked cabinet, bubblers protected from heat etc.).

1128. In addition to the design aspects, the following aspects contribute to demonstrating BAT for the sampling techniques:

- Appropriate sampling equipment is selected.
- Appropriate sampling procedure in line with relevant standards and regulatory guidance.
- The size of samples is commensurate with that required by the analysis laboratory and with provision of spare material for repeat analyses and (if required) sample archiving.
- Appropriate arrangements for testing and calibration of equipment.

a) Evidence 179: Arrangements for monitoring and sampling of aqueous discharges

1129. The arrangements in place for monitoring of discharges were defined in the EOS1 reports [Ref 180] and are summarised in RSR Permit Application Support Document C1 [Ref 6]. The tank sampling and monitoring components are part of the TEN, the discharge line monitoring is considered part of either KER or SEK and the KRT provides gamma monitoring on the KER discharge line only. During operation the tanks will be sampled from the recirculation line via the TEN sink. This will be used to determine if the tank contents are suitable for discharge. During the discharge, the proportional flow sampler will provide a sample that will be used for discharge reporting along with flow rate and volume measurement from the flow meter. Redundancy of the volume measurement is provided by the tank level sensors and has therefore been specified to provide the same level of uncertainty as given in the MCERTS requirements. KRT monitoring is performed on the KER discharge line to detect any increase in activity and ensure the isolation of the line to prevent further discharge in the event of high activity being detected in the line.

1130. Following sampling, the next stage for the determination of radioactivity discharged involves measurements and assessment, where the discharge assessment brings together the sample analysis result and the volume of effluent sampled and discharged, so that a final discharge value can be calculated and reported.

1131. The KER and SEK's represent the main discharge pathways for radioactive liquid effluent from the Nuclear Island and site facilities and as such are identified as the Main Outlets of disposal of aqueous waste. TER is also identified noting that the final discharge route is via the KER discharge line. These systems are as follows:

- **KER: The Liquid Radwaste Monitoring and Discharge** System which collects, monitors and discharges treated effluent from the Nuclear Island direct to the discharge outfall.
- **TER: Additional Liquid Waste Discharge System** which provides backup capacity for storing liquid effluent. This system does not have a separate discharge line and is discharged via the KER network.
- **SEK: The Site Liquid Waste Discharge System** which collects, monitors and discharges liquid waste from the Conventional Island, including the Turbine Hall and effluent from the Nuclear Island that is not normally active direct to the discharge outfall.

1132. Tanks will be sampled prior to each discharge. UK best practice will be applied:

- The tanks will be sampled prior to discharge to allow analysis to authorise the discharge, during which time no further inputs to the tank will be permitted and a different tank will become the duty tank for collection of effluent.

- Once a tank has been authorised for discharge, a flow proportional sampler, located on the discharge line, will collect a representative sample throughout the discharge. The sample will be analysed, and the results used for statutory reporting. The line is also fitted with a flow meter to provide accurate flow date from which the discharge figures can be calculated.

1133. The design of the minor outlets will include provisions for manual sampling to enable to check, at an appropriate frequency, that the radioactive discharges from these outlets remain below 5% of the respective discharge limits specified in the RSR permit.

1134. Design change T2WIT-10603 [Ref 125] details updates made to the aqueous discharge system design to ensure no unmonitored discharges will be made to the environment by automatically closing final discharge valves in the event the representative samplers from the KER and SEK tanks are unavailable; thus, ensuring compliance with the RSR permit conditions requiring demonstration of control and knowledge of all discharges made to the environment.

b) Evidence 180: Provision for independent sampling of aqueous discharges

1135. Means for independent sampling will be provided to allow the Environment Agency to take independent samples of aqueous discharges for analysis as part of regular inspections of nuclear sites to ensure compliance with the conditions of the permit and this may include taking samples for independent analysis. The independent sampling will be from the same locations as used by SZC Co. for self-monitoring of the plant and all data and quality control information will be made available to the regulator for inspection.

1136. The Environment Agency will be able to witness the sampling, measurement and assessment process and obtain relevant samples for their own analysis as required for liquid discharges. This arrangement does not require duplicated or separate sampling equipment as relevant samples can be obtained from the existing flow proportional sampling equipment.

1137. The design of the proportional flow sampler installation will enable access to the EA to ensure that witness sampling is possible.

c) Evidence 181: Sampling techniques for aqueous discharge monitoring

i. Flow Proportional Sampler

1138. In order to provide accurate data for discharge reporting the EOS1 report [Ref 181] confirms that samples are taken from the discharges lines by a FPS allowing for analysis off line of specific radionuclides. The use of a FPS is also in line with the Environment Agency Technical Guidance Note [Ref 187], which states that sampling of batch discharges may be carried out by taking composite samples from the discharge line using a FPS. The FPS will provide a composite sample covering the discharge of each batch which is considered to be a single tank. Any subsequent tank will be treated as a new batch and a new composite sample taken; the tank is recirculated prior to and throughout the discharge to ensure a homogenised, representative, effluent sample is obtained.

1139. The final design of the FPS is not yet confirmed, however, it has been demonstrated in the EOS report [Ref 181] that Constant Volume Variable Time (CVVT) based proportional sampling will be used to take the sample. In order to ensure the volume of effluent obtained will provide sufficient sample to enable routine analysis, annual bulk analysis for gamma, beta and alpha emitters for reassurance purposes and to inform Pollution Inventory returns as well as any regulatory or QA purposes, a minimum sample size of 4 litres is required. This volume is a minimum requirement regardless of the overall discharge volume. Given that the tanks for HPC will hold up to approximately 750m^3, the aliquot sample size and frequency shall be optimised as far as reasonably practicable to achieve representative sampling. The aliquot size and frequency will be confirmed following feedback from supplier giving consideration of the system flow rate.

1140. In order to sample the radionuclides as specified in the permit and to provide accurate data for discharge reporting, the EOS1 report [Ref 181] confirms that samples can also be taken from the tank prior to discharge allowing for analysis off line of specific radionuclides. This technique ensures effluent is ready for disposal and also provides a diverse back up to samples taken via the FPS. This is in line with the Environment Agency Technical Guidance Note [Ref 187] which states that sampling of batch discharges may be carried out by the mixing and sampling of tank contents.

1141. These samples will be of a similar volume to those taken via the FPS given that samples obtained via the TEN sink may provide back up to the FPS.

1142. A further study [Ref 75] demonstrates that the valve configuration for the discharge tanks will be isolated and no additional effluent added following sampling.

1143. Although the MCERTS requirement does not yet apply to FPS in pressurised systems, SZC will ensure that the design complies with the equivalent requirement of BS EN 16479 [Ref 188].

ii. Flow meter

1144. In order to provide accurate data for discharge reporting the flow of the discharge shall be monitored on the discharge lines by a flow meter. The use of a flow meter is also in line with the Environment Agency Technical Guidance Note [Ref 187] which states flow meters can be used to provide the total volume over the discharge period. The flow meter is required to comply with MCERTS and SZC Co. has specified the use of a MCERTS flow meter from an approved supplier, which will be subject to certification after installation. The final detailed layout will also be assessed to ensure these installation requirements are met.

1145. A BAT report [Ref 189] presents the high level assessment of the aqueous discharge sampling arrangements and confirms the use of flow meters for KER and SEK discharges.

d) Evidence 182: Optimisation of the location of liquid effluent discharge sampling points

i. Flow Proportional Sampler

1146. FPS connections shall be located on the KER and SEK discharge lines downstream of any abatement and upstream of the final discharge valves. This is consistent with the requirements of the Environment Agency TGN M12 [Ref 187] which requires sampling to be carried out downstream of any abatement plant but upstream of any point where further dilution of the waste stream occurs. The location on the discharge line means that it is truly representative of the effluent discharged at the time of discharge. In addition, it is considered good practice to maximise the distance to the nearest flow disturbance as required by the Environment Agency TGN M18 [Ref 190]. The layout ensures 5ND upstream and downstream of the FPS sampling lines

1147. The FPS units are located as close to the point of discharge sampling as reasonably practicable. Within the HXA BES [Ref 191] the location of the FPS units is provided demonstrating that the layout confirms the sampling line length as approximately 5m for SEK and 9m for KER. This layout meets the ASTM standard [Ref 192] and SZC BAT criteria to make the sample lines as short as possible taking into account operator access and radiological protection. Additional information relating to location requirements are given under the design of the sample line evidence (see Sub Argument 50).

ii. TEN sampling sink

1148. The TEN sampling sink enables collection of a tank sample prior to discharge. Once the tanks are sufficiently mixed a sample is taken from the sink via the recirculation line. This ensures that the sample taken is representative of the content of the tank and means that a sample can be taken and analysed before entering the discharge line. The recirculation line, sampling line and sink are all located in the HXA.

1149. The recirculation line and sampling lines are routed to the sampling sink located in a room adjacent to the storage tanks. In order to minimise the operator burden expected when installing a sampling sink in higher traffic areas, which is a radiological yellow zone next to each recirculation line, a single sink, located in a dedicated sampling room has been provided. This sink will be located in a radiological green room and will be connected to each recirculation line via a sampling line. The detailed location of the sampling line is subject to final detailed design however it has been confirmed that the line will be turbulent as also required in M18.

iii. Flow meter

1150. An EOS [Ref 181] demonstrates that to ensure representative sampling of the discharge, sampling equipment shall be located on the KER and SEK discharge lines downstream of any abatement and upstream of the final discharge valves. The location of the flow meters on the discharge line means that it will allow for a representative sample of the volume of effluent discharged to be taken.

1151. The location of the flow meters is also a significant requirement of the MCERTS standard [Ref 178]. The layout of the discharge pipes and the flow meter has been confirmed in the HXA BES [Ref 191]. This confirms there are:

- no bends or valves are within 0-5 diameters (1m) upstream or 0-2 diameters (0.4m) downstream of the meter;
- no incoming branches are within 0-5 diameters (1m) upstream of the meter;
- no pumps are within 0-20 diameters (4m) upstream of the meter;
- no conical contraction or expansion within 0-5 diameters (1m) upstream of the meter;
- flow meters have been positioned in the vertical direction to prevent any fouling of the sensors; and,
- there are no other electromagnetic devices within 0-5 diameters (1m) upstream or 0-2 diameters (0.4m) downstream of the meter.

1152. This is illustrated via an image of the 3D model shown in Figure E1 in Appendix E of [Ref 171].

iv. Tank level sensors

1153. In order to provide a redundant means of measuring the volume of effluent discharged, tank level sensors can be used to indicate the total volume of effluent in the tank. These are located in the tank.

e) Evidence 183: Isokinetic conditions for aqueous monitoring

1154. In order to improve the quality of the samples, the rate of sampling should match the rate of flow of effluent in the pipe. Single-port taps are adequate if sufficient velocity is maintained to avoid deposition, whereas multiport nozzles are recommended for obtaining samples containing suspended matter. The sample probe must be oriented so that the probe opening faces the direction of flow. The angle between sampling probe and sampling nozzle should be between approximately 45 degrees and 90 degrees. The EOS1 report [Ref 181] confirmed that in order to demonstrate turbulence, a Reynolds number of >4000 should be achieved. The Reynolds number is a dimensionless number characterizing the flow pattern – the ratio of inertial forces to viscous forces - used to determine whether the flow is laminar or turbulent,

1155. Isokinetic recommendations have been taken into account and integrated in the design as recommended by international experts (EPRI, IAPWS) and in compliance with relevant standards:

- It is internationally recognized that isokinetics conditions (i.e. rate of sampling matching the rate of flow in the sampled pipe) are difficult to achieve for liquid sampling. It is admitted by EPRI and IAPWS experts that isokinetics may not be critical for ensuring representativeness of the samples so long as turbulence criteria are met at the sampling location and the sampling nozzle appropriately protrudes into the sampled pipes and points upstream as appropriate.

- Turbulence is ensured at the sampling location (Reynolds Number significantly higher than 4,000).
- Turbulence is ensured in almost all the sampling lines (Re higher than 4,000 in all the sampling line). Where the flow is laminar in the sampling line, number of bends, low points, dead ends/legs and length of the sampling line are minimised.
- The sampling line is equipped with a nozzle which protrudes as appropriate into the sampling pipe. The sampling nozzle points upstream to the flow direction.

1156. As demonstrated in [Ref 181], according to existing international studies, compliance with isokinetic conditions is not needed in case of liquid samples if the sampling point is adequately located and designed. This requirement is essential in regions of low flow or whereby tank contents have not been mixed allowing entrained larger particles to settle. Isokinetic requirements as defined in the Environment Agency M12 guidance [Ref 187], including the use of a single or multiple port nozzles to contribute to isokinetic sampling, is dependent on the size of the sample line and velocity of discharge and will be confirmed in a BAT assessment as part of detailed design.

1157. The flow meter is electromagnetic and does not require a separate sampling line.

1158. The tank level sensors do not require a separate sampling line and are unrelated to isokinetic conditions.

f) Evidence 184: Representative sampling techniques for liquid discharges

i. Flow Proportional Sampler

1159. For liquid effluents, rather than a single grab sample, the flow proportional sampler (FPS) will provide a composite sample of small samples (aliquots) taken at predefined flow rates ensuring that the sample of the discharge is as representative as reasonably practicable. The EOS report [Ref 181] confirms that the strategy is for CVVT based proportional sampling (as opposed to time based) whereby samples of equal volume will be collected at frequencies proportional to flow in order to allow for flow fluctuations and therefore ensure a representative sample is collected. This sampling principle is based on the MCERTS guidance [Ref 193].

1160. In addition to the principle of taking a composite sample to optimise representativeness, the conditions in the sample pipe were assessed against the ASTM standard [Ref 192] requirements. Representativeness at the point of sampling has been achieved by optimising the velocity and using inert and corrosion resistant materials for the pipe with a surface roughness less than or equal to 12.5 µm. The Environment Agency guidance M18 [Ref 190] states that samples shall be taken from regions of high turbulence so that solid materials have little chance to settle out. The EOS1 report [Ref 181] confirmed that in order to demonstrate turbulence, a Reynolds number of >4000 should be achieved. The Reynolds number is a dimensionless number characterizing the flow pattern – the ratio of inertial forces to viscous forces - used to determine whether the flow is laminar or turbulent.

ii. TEN

1161. For the TEN sampling sink, representative sampling of the tanks is initially ensured by ensuring a homogenised mix before sampling. As described in the EOS1 [Ref 181], the required mixing time depends on the tank volume and flow rate of the pump and will be determined by the operator.

1162. The pumps located on the recirculation line are capable of re-circulating the tank contents at flow rates between 0 - 350 m^3/h noting that high mixing flow rates allow for quicker homogenisation.

1163. In addition, the design of the discharge tanks has been optimised to minimise the risk of sedimentation and retention of particulate that may become dislodged post tank sampling. The EOS [Ref 74] demonstrates that the tank will include sloped tank floors and suitable surface finish (304L) which will minimise the risk of sedimentation and retention of particulate.

1164. Once the tank contents are homogenous a sample will be taken. The design of the sampling line (see Sub Argument 50) will ensure the sample remains representative at the point of collection in the sink. Additionally, the sink allows for flushing of sample lines to avoid cross contamination.

iii. Flow meter

1165. The MCERTs standard [Ref 178] requires that the measured target of uncertainty shall be no greater than +/- 8% at a confidence level of 95%. This is achieved through a combination of the equipment specification and consideration of the effects due to flow disturbances in the installation. Within Appendix 3 of the MCERTs standards, an uncertainty range is given for any disturbances within a specified distance. There are no disturbances within the HPC RC1.2 design which would impact the level of uncertainty through the installation and therefore the current arrangements would not foreclose options for the type of equipment in order to stay within the +/- 8% level of confidence. Representativeness of the flow meter will also be verified by MCERTS certification after installation and by independent analysis whereby a second flow meter can be used to measure the flow on the same line.

iv. Tank level sensors

1166. MCERTS standards do not directly apply to tank level sensors however they will also apply BAT through the consideration of relevant good practice. In the absence of any other standards, the MCERTS requirement will be applied as relevant good practice. As such the supplier will be required to ensure that the measurement level of uncertainty does not exceed +/- 8%. This will be confirmed by the supplier through their EDS which will be reviewed by SZC prior to commissioning.

g) Evidence 185: Optimisation of the design of the liquid effluent sampling line

i. Flow Proportional Sampler

1167. For liquid effluent the design of the sampling line of the sampler shall minimise the possibility of its clogging by suspended solids in the waste water. This is done through the use of suitable material, in this case stainless steel 304L which is inert and corrosion resistant (a requirement of the ASTM standards [Ref 192]), and the optimisation of the nominal internal diameter of the sample line and effluent velocity through it. BS EN 16479:2014 [Ref 188] and MCERTS [Ref 193] requires that the sampling line internal diameter should not be less than 9 mm and the average sample line velocity should not be less than 0.5 m/s.

1168. The piping specification [Ref 194] confirms that the internal diameter of the FPS sampling pipe is 9.22mm, conforming to the requirement of the standard; for the TEN sink sampling pipe it is 17.08 mm and again, conforms to the requirement of the standard. The design requirements for pressurised systems [Ref 195] states that if the pressure is less than or equal to 50 bar the speed should be between 1 and 3 m/s. This reduces the vibration of the pipework and minimise the risk of line breakage. This confirms that the sampling line design meets the MCERTS [Ref 193] requirement to prevent clogging of the sampling line.

1169. The Environment Agency guidance M18 [Ref 190] requires that the end of the sampling pipe must protrude into the sampled effluent and Environment Agency TGN M12 [Ref 187] requires that the direction of the probe/nozzle faces the direction of flow. These aspects of the sampling line design have not yet been completed and are subject to detailed design. Overall the current design of the sampling line optimises the ability to take a representative sample; any further design detail will only optimise this further.

ii. TEN

1170. Given that a single TEN sink has been provided in a dedicated sampling room the sampling line lengths will be subject to supplier feedback and detailed layout design. The number of low points in the TEN shall be minimised to prevent sedimentation settling out in the sampling lines, which may distort the representativeness of the analysis results and produce "hot spots" as well as inaccurate discharge returns to the regulator.

iii. Flow meter and tank level sensors

1171. The flow meter (electromagnetic) and tank level sensors do not require separate sampling lines.

h) Evidence 186: Safe and suitable access is provided for aqueous sampling equipment

1172. The sink provided for sampling discharge tanks and the discharge line FPS and flow meter are located in the basement of the HXA building. Access to the HXA building is for authorised personnel only via the Radiation Controlled Access Point. The HXA BES [Ref 191] demonstrates that suitable and safe access has been ensured in the design of these buildings. In order to demonstrate available space for equipment at this stage of the design whereby the final equipment has not yet been procured, SZC has used OEF from Sizewell B (SZB).

i. Flow Proportional Sampler

1173. A key consideration factor for ensuring suitable space is available for equipment (including for its maintenance) is the spatial requirement for other services that may be used during the operation or maintenance of the equipment. Within the Environment Agency TGN M12 [Ref 187], it is recommended to have appropriate facilities including electricity, lighting, water supply and drainage. The design of the KER and SEK's include provision for a compressed air supply, drainage and ventilation directly to the FPS. A demineralised water supply is available upstream of the FPS if required and as the water supply is located locally further connection can be made to the FPS if required.

1174. The FPS used at SZB provides the dimensions for a single FPS as 1.6 meters in height, 0.5m width and 0.37m depth.

1175. The final layout of equipment within this room will be confirmed at D2 stage following feedback from the equipment supplier. The layout as shown in Figure E2 in Appendix E of [Ref 171] confirms that the most restricted space on the access route to the FPS is between the wall and the SEK tank. This access space is greater than the expected width of the equipment ensuring that replacement of the FPS is possible. Overall the building design stage (D0) demonstrates sufficient space has been allocated to ensure that construction activities will not foreclose options for sampling equipment purchased later.

ii. TEN sampling sink

1176. The sampling sink room is provided in the HXA building, which measures 4.75m by 4.5m. This is a dedicated area with one sampling sink provided, to which the all the TEN sample lines from the KER, SEK and TER tanks will be routed. The use of a single sink in a dedicated room minimises operator burden and risk (less traffic and less time spent in a radiological yellow zone). This sink will be connected to each recirculation line via a sampling line. The detailed location of the sampling line and final layout of equipment within this room will be confirmed at D2 stage, however, the building design (D0) demonstrates sufficient space has been allocated to ensure that construction activities will not foreclose options for sampling equipment purchased later.

1177. The design of the TEN sink is subject to supplier feedback, however, it required that sufficient splash guards for the protection of the operators during sampling are provided as well as a flushing facility to provide routine rinsing of the sink to avoid build-up of contaminants.

iii. Flow Meter

1178. Space has been provided for the flow meters, and additional space is provided to enable a second flow meter to be placed on the discharge line to enable verification as per the MCERTS [Ref 178] requirement. As per the requirements for new installations in Appendix 3 of the MCERTS standard this is at least 450mm.

1179. Overall the building design stage (D0) demonstrates sufficient space has been allocated to ensure that construction activities will not foreclose options for flow meter equipment purchased later and will ensure compliance with the MCERTS requirements.

iv. Tank Level Sensors

1180. The tank level sensors are located within the KER, TER and SEK tanks which are situated in the HXA building. Routine access to the level sensors is not required and measurement is provided on the panel in the HQB building. The design of the tanks and associated sensors (there are also temperature sensors location in the tanks) do not impact the overall arrangements for liquid sampling.

1181. Access to the tank level sensors during routine operation is not required. Given that the sensors are located inside the tanks, the design of the tanks will allow for access to the sensors when required for maintenance and inspection purposes.

i) Evidence 187: Alarms, automated actions and back-ups for liquid effluents

1182. The Environment Agency TGN M12 [Ref 187] requires that equipment should be fitted with an alarm (sounding or display) in case of failure of equipment. The design of SZC includes a signal sent to the operator to alert of equipment failure meeting this requirement.

i. Flow Proportional Sampler

1183. The EOS1 [Ref 181] states that I&C programming could be required to prevent discharge when the proportional flow sampler is unavailable. This will ensure that the final discharge valve, tank out valve and pump will close/stop to prevent discharges in the event of FPS failure. This design feature has been implemented for HPC and will be included for SZC. This replaces the requirement for back up FPS equipment. The back-up samples for discharge reporting can be provided by tank samples only if required in exceptional circumstances.

1184. The FPS will be fitted with appropriate alarms to warn operators of equipment failure; the specification for the use of local alarms will be confirmed during the procurement of equipment.

1185. The discharge line is also monitored to indicate high pressure/temperature and low flow rate. Automatic isolation of sampling lines is included in case of high pressure/temperature to protect equipment and operators (see Sub Argument 55).

ii. TEN sink sampling

1186. The temperature of the TEN sink sampling line will be monitored by the tank temperature sensors prior to sampling, or by local sensors and display and does not require any alarms or automatic actions. As operation of the sinks is undertaken manually by the operator following procedural control, there is no additional requirement for alarms or back up.

iii. Flow meter

1187. Automatic isolation of the flow meter will occur in the event of equipment failure. This ensures that the final discharge valve, tank out valve and pump will close/stop to prevent unmonitored discharges.

1188. Given that the flow meter is external to the pipe, the pressure and temperature measurement to protect equipment is not relevant.

iv. Tank level sensors

1189. Tank level sensors will be used at SZC, the final specification will be confirmed at detailed design and included in the SDM.

j) Evidence 188: Radiological protection for operators for liquid effluent sampling and monitoring

1190. Room access for operators will be subject to a task-based radiation risk/ALARP assessment by the site RPA. If dose rates approach the R3 maximum, then worker access may be challenging. It is not considered good practice to access designated areas via areas of a higher radiological designation (R2 via R3).

i. Flow Proportional Sampler and Flow meter

1191. The room where the FPS and flow meter are located has a radiation protection classification of R3, which is a controlled area where the dose to operator may be between 25µSv/h and 0.5mSv/h. Operator dose rates are considered low enough that it does not require additional access controls. The R3 classification is due to the possible inventory of the PTR storage tanks. However, the FPS and flow meter are located behind the SEK tanks, which are not expected to contain contaminated effluent and provide intrinsic shielding reducing the risk to operators. There is no additional shielding requirement for carrying out activities in this area. Transit times in personnel passing the PTR tanks will be minimal. Overall, the risk to operators is minimised so far as reasonably practicable.

ii. TEN sampling sink

1192. The room where the TEN sink is located has an R2 radiation classification, which is a controlled area where the dose to an operator is not expected to exceed 25µSv h^{-1} and therefore does not require additional access controls. Access to the room is through the tanks room, which is an R3 area. However, the tanks with the highest dose rate are at the furthest point away from the access route to the sampling sink room. This demonstrates that access to the TEN sink ensures that operator radiation exposures are ALARP.

iii. Tank level sensors

1193. Access to the tank level sensors during routine operation is not required. Given that the sensors are located inside the tanks, the design of the tanks will allow for access to the sensors, when required, for maintenance and inspection purposes.

iv. REN/RES Laboratory

1194. The REN/RES lab is located in the HN building and is capable of storing and analysing both liquid and gaseous samples. Access to the laboratory itself is controlled to ensure operator safety and will be fitted with appropriate gloveboxes, drainage and ventilation to minimise any risk to the operator. Any high dose areas, such as in-process sampling lines are in a separate area to the analytical benches.

k) Evidence 189: Operation and maintenance of the liquid effluent sampling system

i. Flow Proportional Sampler

1195. The MCERTS performance standard [Ref 193] has generic requirements for the FPS that will also support the operation and maintenance of the FPS. Whilst this standard may not be applicable to FPS in pressurised systems, SZC intend to apply this standard, where appropriate, and, subject to feedback from the equipment supplier, with the final specification being confirmed by the supplier, in an Environmental Analysis Report following receipt of the equipment.

ii. TEN sampling sink

1196. In order to ensure operator safety, the supplier of the sink is also required to consider all the necessary sensors, namely thermocouples welded on the sampling line externals with a local reading of sample temperature next to the related gloveboxes/sink, in order to allow the operator to check that fluid is suitable for sampling. This risk is, however, reduced as the tanks themselves are equipped with temperature sensors and alarms meaning that the operator can determine the temperature of the sample prior to sampling.

1197. The TEN sampling sink has drainage provided by the Nuclear Island Vents and Drains system (RPE) to collect any spillages when collecting a sample. Disposal or recycling of the sample itself will be carried out in the laboratory and is managed through its procedural controls.

iii. Flow meter

1198. An additional requirement in the MCERTS standard [Ref 193] is that new installations shall have sufficient exposed pipe available to install a clamp on the flowmeter for verification purposes. The greater of 450 mm or 1.5 pipe diameters is recommended as a minimum. This has been verified in the HXA BES [Ref 191].

iv. Tank level sensors

1199. Access to the tank level sensors during routine operation is not required. Given that the sensors are located inside the tanks, the design of the tanks will allow for access to the sensors when required for maintenance and inspection purposes.

l) Evidence 190: Optimisation of temperature, pressure and flow-rate conditioning for the liquid effluent sampling and monitoring system

i. Flow Proportional Sampler

1200. As per the KER P2 [Ref 196] flow measuring orifice plates are fitted on the large flow and small flow discharge lines respectively. In addition, an electromagnetic flow meter is fitted immediately upstream of the interface for the discharge line and FPS, the flow meter measurements ensure a constant flow rate as a closed loop control for the valves. If the flow rates exceed a maximum value, then the discharging pump will automatically shut down to protect the pump from cavitation.

1201. The storage temperature is expected to be between 10ºC and 60ºC [Ref 197] which is monitored by the tank temperature sensors. The maximum pressure is given as 10 bar g [Ref 197] and is controlled by pumps, and the upstream pressure is monitored. The proportional flow sampler will be designed to operate within these conditions.

ii. TEN sampling sink

1202. The temperature of the TEN sampling sink effluent can be monitored within the tanks and dependent on supplier feedback this may also be available at the point of sampling. Again, as this is a passive system the operation of the sink itself is not impacted by the conditions.

iii. Flow meter

1203. Conditioning is not required for operation of the flow meters however the maximum pressure is given as 10 bar g [Ref 197] which is controlled by pumps, and the upstream pressure is monitored. The flow meters will be designed to operate within these conditions.

iv. Tank level sensors

1204. The sensors are located inside the tank and therefore only impacted by conditions in the tank. The storage temperature is expected to be between 10ºC and 60ºC [Ref 197] and the sensors are required to operate under these conditions. Effluent contained within the tanks contains no other properties which would adversely affect the sensors.

m) Evidence 191: Protection of the liquid effluent sampling equipment

1205. The Environment Agency TGN M18 [Ref 190] requires that equipment is protected from adverse environmental conditions.

i. FPS, TEN sampling sink and flow meter

1206. Although this requirement is not directly applicable to the liquid sampling equipment, it is not anticipated that the discharge pipework of the FPS, TEN sampling sink or flow meter will be subjected to extreme temperatures as they are housed and sampled within the HXA building, which is ventilated by the DWV HVAC system ensuring adequate ambient conditions. Given that the temperature within the rooms will remain above 5ºC, trace heating of sampling lines is not required within the building [Ref 181].

1207. In addition, the discharge lines and flow meters are located in a low personnel traffic area, so minimising the risk of damage from other activities.

ii. Tank level sensors

1208. The sensors are located inside the tank and therefore only impacted by conditions in the tank. The storage temperature is expected to be between 10ºC and 60ºC [Ref 197] and the sensors are required to operate under these conditions. Effluent contained within the tanks contains no other properties which would adversely affect the sensors.

n) Evidence 192: Recycling of samples

1209. When returning the samples to the system, the samples will be returned downstream of the original sampling point, but before any further abatement processes. In some cases, it may be required that a sample be returned to the effluent after an abatement. In this case, the BAT implications of discharge of the sample unabated will be considered before implementation.

1210. In some cases, the sample will not be returned to the system. In such cases, the liquid samples will be disposed of to the appropriate drain.

6.5.6 Sub-Argument 30: Appropriate in-process monitoring is undertaken and optimised for aqueous effluents

1211. Adequate arrangements are implemented prior to discharge of liquid effluents, to enable the operator to:

- understand individual system contribution to discharges so that management of waste can be optimised going forward;
- identify where increases in discharge results may come from within the plant including identification of leaks;
- ensure automatic containment or alarm in the event of activity (increased) detection; and,
- use results for the validation of the function and performance of EPE.

1212. As covered in Sub-Argument 27 for gaseous in-process monitoring, SZC Co. has considered guidance, best practice and OEF worldwide in order to identify the best practice when it comes to sampling techniques and optimisation.

1213. As part of the EOS1 studies [Ref 180] [Ref 181] [Ref 169] to determine that the sampling arrangements were BAT, BAT assessment criteria were jointly defined by NNB GenCo (HPC) and RD throughout workshops. These criteria and the conclusions reached in the EOS1 report were reviewed in 2018 as part of NNB GenCo (HPC) work to contribute to closure of HPC IC4 of the HPC RSR permit, and given the sampling arrangements are retained for the SZC design, they are considered appropriate for the SZC project. The criteria are based on relevant standards, regulatory guidance and best practice, including:

- Environment Agency guidance, in particular Technical Guidance Note M12, M18 and MCERTS;
- relevant national and international standards (EPRI, IAPWS);
- relevant EDF standards; and,
- EDF PWR fleet OEF and best practices.

1214. Whilst the BAT assessment criteria considered differ to that of gaseous effluents, they are grouped into the same five categories:

- Location of the sampling point (contributing to representativeness of sampling/on-line measurements).
- Isokinetics (also contributing to representativeness of sampling/on-line measurements).
- Representativeness (other than location and isokinetics).
- Operation and maintenance.
- Other principles (any other applicable recommendations, including civil work constraints).

1215. They are established to ensure that the design of sampling and monitoring systems adequately delivers the monitoring strategy and enables representative sampling. They also ensure that there is sufficient space for sampling and monitoring equipment, suitable sampling arrangements, suitable and safe access to sampling and monitoring equipment and suitable environmental conditions.

a) Evidence 193: Arrangements for in-process monitoring and sampling of aqueous effluents

1216. **Table *6-9*** below gives a summary of the information presented for the monitoring equipment that was covered by [Ref 25] and will be considered in stage 1 of the report. The table also provides the KRT function associated with the monitoring.

Table 6-9 Monitoring equipment information summary

System	Type of monitoring	Purpose of monitoring	KRT role
RCP	Global Gamma	Trending of activity in the primary circuit and detect any rise in activity.	Class 1 activity detection and automatic containment action
RPE	Global Gamma	Detect rise in activity of sumps.	Class 2 and 3 dose rate detection and automatic containment action

System	Type of monitoring	Purpose of monitoring	KRT role
TEU (Liquid Waste Processing)	Global Gamma	Detect a rise in activity of the distillates and contamination of the evaporator boiler circuit.	Class 3 activity detection and automatic containment action
RRI and TRI (Component Cooling)	Global Gamma	Identification of leaks	Class 3 activity detection and alarm in main control room
APG (Steam Generator Blowdown)	Global gamma	Post-accident monitoring	Class 3 post accidental monitoring

1217. A BAT assessment [Ref 118] has been carried out for TEU distillates monitoring. This report determines the appropriate monitoring of effluent following treatment in the TEU evaporator (TEU distillates) which is required to:

- Assess the DF of the evaporator to enable compliance with condition 2.3.5 of the standard RSR permit template [Ref 20].
- Assess the activity of TEU distillates against the end-of-treatment decision threshold (DT) to be defined by the operator, to determine whether the TEU distillates are suitable for discharge to KER (where they will be subject to further sampling and analysis), or whether additional treatment is required – this will enable compliance with condition 2.3.2 (a) of the SZC RSR permit.
- Quantify the activity of TEU distillates discharged to the KER tanks for trending purposes and to help identify the root in case of exceedance of a QNL – this will enable compliance with condition 4.3.7 of the SZC RSR permit.
- The BAT assessment concludes that addition of FPS on the TEU discharge line, and I&C modification to the KRT monitor in the evaporator loop to ensure that distillates are only discharged to KER/TER when appropriate is suitable.

1218. Options Assessment for the SBE [Ref 198] system included sampling lines to the TEN to assess activity & quality of the effluent discharged for the system. Circulation of the content of the tanks provides agitation for representative sampling via 9TEN. This helps to ensure compliance with discharge permits and reduces particulate accumulation on tank internals. The system design already includes recirculation; further optimisation is dependent on operational requirements [Ref 114].

1219. Design change CFSE0419UK Optimisation of control of TEUdistillates determined that the design change could have the potential to impact the monitoring of evaporator performance and the representativeness of such monitoring, the segregation of liquid wastes and ultimately impact the quality of effluent sent to the KER. An Environmental Optimisation Study (Appendix 7 of [Ref 112]) was completed to assess a number of options to determine the BAT option for monitoring effluent following treatment by the evaporator and prior to discharge to the KER. The addition of a flow proportional sampler of the distillates discharge line along with the use of the radiation monitor to detect when effluent was suitable for discharge to KER and to provide a representative sample for full analysis was concluded as the BAT option.

1220. As per the BES for 2/9RPE [Ref 215], the design of the 2/9RPE allows sampling of the sump effluents through a manually operated valve on the sump mixing lines [Ref 8]. The purpose of the sampling is to identify whether there is any out of specification effluent in the sump, which would need to be treated by 9TEU in a different way to normal. For example, in a sump which usually contains floor drain effluent, some chemical contamination may occur, which would necessitate treatment on the evaporator.

1221. Although re-routing of effluent from the discharge of the 2/9RPE sumps is not possible, the early detection of out of specification effluent allows the volume of effluent that is contaminated with this out of specification effluent to be minimised.

1222. The BES for the 9PTR [Ref 216] confirmed that the design of 9PTR allows sampling on the recirculation line. The exact location of the 9TEN connection on the recirculation line has not been chosen yet because the 3D model of the recirculation line with its bends and routing is not done yet. Because of the 9TEN connection has not been yet implemented in HXA this is captured as an open point in the open point register [OP 168] [Ref 174].

b) Evidence 194: Arrangements for in-process sampling of aqueous effluent in tanks and sumps is optimised

1223. When sampling liquid effluent in a tank or sump for in-process monitoring purposes, the sampling point should be placed on a recirculation line to enable mixing of the effluent before sampling. If there is no recirculation line, mixing of the contents of the tank/sump should be carried out before sampling.

1224. In case of tanks/sumps where permanent circulation is not ensured, the fluid has to be homogenised by mixing before sampling. The required tanks' mixing time depends on:

- tank volume;
- mixing flow rate achievable; and,
- specificities of tank's design.

1225. To obtain a representative sample from large volumes of water contained in the fuel pools (in HK and HR) and the IRWST, permanent recirculation must be ensured. This is the case in the SZC UK EPR^{TM} design.

c) Evidence 195: Optimisation of monitoring techniques used for aqueous effluents

1226. The RSR permit granted to for the disposal of radioactive waste from Sizewell Point C will require the operator to demonstrate that BAT has been applied. In order to demonstrate compliance with all such conditions EOS have been produced in order to provide specific details related to the monitoring of:

- design and selection of techniques for sampling of in-process radioactive liquid effluent [Ref 180]; and,
- the sampling and monitoring of radioactive liquid discharges [Ref 181].

1227. The reports include a description of the BAT Assessment criteria used and each report includes sections on sampling techniques. Further information is provided in supporting documents [Ref 199] and [Ref 200].

1228. The analysis of in-process aqueous samples is justified in report [Ref 201]. This report identifies analytical techniques allowing the measurement of the different types of activity to be measured in liquid discharges. The aim of this document is to describe the radioactive measurements associated with liquid in-process effluents and discharges which would be encountered at SZC and will be considered as BAT. The description is carried out for each radionuclide or category of radionuclide.

1229. An ALARP assessment [Ref 202] was produced to examine options for reducing dose to the operator in the REN sampling room, whilst ensuring sufficient space for usability of the REN gloveboxes and sampling equipment.

d) Evidence 196: Optimisation of the location of aqueous effluent in-process sampling points

1230. The location of the sampling points has been chosen with respect to international best practices and in compliance with relevant standards:

- The sampling point is placed in a zone where the flow is strongly turbulent and far enough from any disturbance, hence ensuring homogeneity at the sampling location.

    - Strongly turbulent flow at the sampling point (Re higher than 4,000).
    - Nearest upstream flow disturbance:
        - Higher than 10 ND.
        - Higher than 25 ND (in case of chemical injection point (for chemical conditioning of systems) and/or introduction of other streams into the medium to be sampled, for turbulent flow in the sampled pipe).
        - Higher than 50 ND in case of chemical injection point (for chemical conditioning of systems) and/or introduction of other streams into the medium to be sampled, for laminar flow in the sampled pipe).
    - Nearest downstream flow disturbance to the sampling probe – Higher than 5 ND.
    - Avoid placing the sampling point near dead legs/ends or low points.
- The sampling point should be as close as is reasonably practicable.
- For tanks sampling, mixing at the sampling location is ensured either by the continuous movement of the effluent or by the localisation of the sampling point on the tank recirculation line.
- The sampling line protrudes into the sampled pipe as appropriate (Immersion equal to 1/3 of the sampled pipe's ND), recognising that increasing the height of the nozzle that protrudes into the sampled pipe can lead to increase stress on the joints and possible accelerated weakening of the joint (increasing sampled pipe leak/break risk).

1231. A full analysis of all in-process sampling and monitoring was undertaken against these criteria in [Ref 181], to ensure they are applied as far as it reasonable practicable (though some criteria are only applicable for certain monitors).

e) Evidence 197: Isokinetic conditions for aqueous in-process sampling

1232. Isokinetic recommendations have been taken into account and integrated in the design as recommended by international experts (EPRI, IAPWS experts) and in compliance with relevant standards:

- It is internationally recognized that isokinetics conditions (i.e. rate of sampling matching rate of flow in the sampled pipe) are difficult to achieve for liquid sampling. It is admitted by EPRI and IAPWS experts that isokinetics may not be critical for ensuring representativeness of the samples so long as turbulence criteria are met at the sampling location and the sampling nozzle appropriately protrudes into the sampled pipes and points upstream as appropriate.
- Turbulence is ensured at the sampling location (Re significantly higher than 4,000).
- Turbulence is ensured in almost all the sampling lines (Re higher than 4,000 in all the sampling line). Where the flow is laminar in the sampling line, number of bends, low points, dead ends/legs and length of the sampling line are minimised.
- The sampling line is equipped with a nozzle which protrudes as appropriate into the sampling pipe. The sampling nozzle points upstream to the flow direction. Preferably the sampling probe should be pointing upstream and the angle between the probe and the nozzle should be 90°. A sampling probe pointing upstream and an angle between the probe and the nozzle of 45° is also

considered as good design.

1233. For all aqueous in-process samplers where isokinetic sampling is required, a full analysis was undertaken against these criteria in [Ref 181], to ensure they are applied as far as it reasonable practicable.

f) Evidence 198: Representative sampling techniques for aqueous in-process effluent

1234. Representativeness requirements have also been taken into account and integrated in the design as recommended by international guidelines (EPRI, IAPWS) and in compliance with relevant standards:

- A turbulent flow is ensured in almost all the sampling lines (Re higher than 4,000). Where the flow is laminar in the sampling line, number of bends, low points, dead ends/legs and length of the sampling line are minimised.
- The number of dead legs/ends, low points and bends are minimized as far as reasonably achievable taking into account civil constraints (for example 18 bends on 173 m of sampling line for RCP Hot Leg 1); the unavoidable bends (due to layout constraints) are gradual thereby limiting the risk of deposition.
- Deposition rate has been minimized notably through:
    - Velocity in the sampling line between 1 and 2 m/s.
    - Use of gradual bends, limited in number.
    - Use of small pipe diameters (ND8, ND6), therefore minimizing conditioning recommendations, reducing lag time and risk of sample composition changes, as well as facilitating flushing and achievement of adequate velocity and turbulence.
    - Ensuring a turbulent flow in almost all the sampling lines.
    - Minimisation, as far as reasonably practicable, of sampling line length.
- Trace-heating to prevent crystallisation) should be provided as appropriate.
- The sampling lines length is mainly driven by the balance between representative sampling and operational factors including human factors to ensure that consistent sampling method can be applied. This is achieved through the centralisation in a common laboratory of glove boxes and on-line measurements with well-established process and procedures to minimise variation in sample collection. This facilitates minimisation of the time taken to transport a range of samples to the appropriate analytical facilities. This reduces operator burden and ensures radiation protection of operators is optimised. The criteria implemented is to reduce sample line length as short as reasonably practicable and less than 300m.
- The sampling pipes and equipment are made of austenitic stainless steel with appropriate internal finish, as recommended for use in nuclear industry since internationally recognised to be inert and corrosion resistant. Internal surface roughness Ra shall be lower than to 12.5µm for mechanical classified systems.
- Appropriate temperature, pressure and/or flow rate conditioning of the samples is ensured by exchangers, pressure reducing valves, flow rate control valves. Monitoring of the efficiency of the conditioning is also provided as appropriate (temperature/pressure/flow rate sensors are installed on the sampling line at different locations). Associated default alarms and automatic actions are provided in the I&C;

- The equipment (valves, exchangers, etc.) installed in the sampling lines upstream of the sample collector/on-line measurement device is limited to the strict minimum. The installed ones are needed to ensure appropriate conditioning of the samples and for maintenances needs. Moreover, as recommended in the standards, valves used are mainly globe valves minimising thus deposition risk and flow disturbances.
- Sampling pipe diameters need to be sufficiently small to ensure transport of samples under turbulent flow conditions. Some systems are sampled for several purposes. To avoid multiple sampling lines protruding into the sampled system, only one main sampling line protrudes into the sampled system and is then divided into several secondary sampling pipes. The main sampling pipe has to be of a sufficient diameter to ensure all secondary sampling lines of a smaller diameter have a sufficient flow to ensure representative sampling. Moreover, to have a sampling of a sufficiently small diameter and to avoid deposition on the reducers, it is recommended to have a sampling pipe with gradual diameter decrease.

1235. A full analysis of all in-process sampling and monitoring was undertaken against these criteria in [Ref 181], to ensure they are applied as far as it reasonable practicable (though some criteria are only applicable for certain monitors).

g) Evidence 199: Operation & Maintenance of aqueous in-process monitoring

1236. The requirements related to operation and maintenance needs have also been taken into account:

- Sample collectors/on-line measurements are located in appropriate areas, with suitable and safe access to equipment for operation and maintenance, and suitable space for maintenance equipment and personnel provided as appropriate.
- The location choices for the sample collectors/on-line measurements (green/yellow areas) ensure operator radiation exposures are ALARP. Some equipment is in an orange area but the operator goes there only for reduced time for maintenance needs.
- The rooms housing sample collectors/on-line measurements are appropriately ventilated by the building ventilation systems to ensure adequate ambient conditions for the operator and equipment;
- The rooms housing sample collectors/on-line measurements are provided with all appropriate facilities and services, such as SED water, gas, electricity, lighting, etc. This facilitates operation and maintenance activities;
- To make operation easier, alarms and automatic actions are provided locally as well as in the laboratory and main control rooms as appropriate. Where needed, high pressure/temperature, low flow rate and equipment failure alarms are provided in the I&C with automatic isolation of the sampling line in case of high pressure/temperature to protect analysers/operators.
- In the event of unavailability of a sampling line, alternative means would provide the required information either directly or indirectly (e.g. redundant sampling line, sampling further upstream or downstream.

h) Evidence 200: Other requirements for aqueous in-process monitoring

1237. Other principles have also been taken into account as recommended by international best practices and in compliance with relevant standards:

- Samples are conditioned in term of temperature, pressure, flowrate as appropriate via one and/or two stages of conditioning (primary and/or secondary conditioning). The efficiency of the conditioning is monitored to ensure samples parameters are as expected (e.g. conditions required at the inlet of the online measurement devices to ensure representativeness of the measurements).

  - Primary coolant samples from REN are recycled to RCV or RPE primary effluent (for treatment before they are returned back to RCP).
  - Secondary effluent samples from RES are recycled to APG.
  - Other samples are recycled back to sampled systems (e.g. RRI, RPE, TEU).

- The sampling line is designed so that adjustments (e.g. pressure, temperature, flowrate) are mainly ensured via automatic or remote controlled equipment (e.g. automatic pressure reducing valves). This minimises operator burden and reduces operator radiation exposures.
- Appropriate protections of equipment from adverse environmental conditions and unauthorised personnel interference are in place:
  - Access to the HN and Effluent Treatment Buildings (HQA/B/C) is controlled (within RCA).
  - Appropriate ambient conditions for equipment are ensured (appropriate ventilation sizing, etc).

1238. A full analysis of all in-process sampling and monitoring was undertaken against these criteria in [Ref 181], to ensure they are applied as far as it reasonable practicable (though some criteria are only applicable for certain monitors).

i) Evidence 201: Analysis and assessment of radioactive aqueous effluents

1239. Analysis of radioactive aqueous discharge samples will provide representative measurements of the radioactivity discharged to the sea. Discharge samples will be provided by:

- pre-discharge tank samples taken from the main discharge tanks (KER, TER and SEK); and,
- flow proportional samples taken from the main discharge outlet pipework.

1240. Where deemed appropriate minor outlets may also be periodically sampled and analysed.

1241. The pre-discharge tank samples will be analysed for the radionuclides and group of radionuclides that are subject to discharge limits in the SZC RSR permit. Analysis will be undertaken in the HN building laboratory prior to discharge and the results will be used to authorise the discharge. Appropriate controls will be in place to ensure that the right procedures have been used and that the discharge limits are complied with.

1242. The flow proportional samples will be analysed in the HN building laboratory for all radionuclides and groups of radionuclides that are subject to discharge limits in the SZC RSR permit. The results will be used for discharge assessment. If the FPS fails, the pre-discharge tank sample analysis can provide the evidence for discharge reporting.

1243. Annual bulk samples will also be analysed. When required an off-site laboratory may be used for analysis of radionuclides including but not limited to nickel-63 and iron-55, pure beta emitters and alpha emitters.

1244. On-line detectors will continuously measure global gamma activity on the KER-TER discharge line. This is not for reporting purposes but to prevent an unauthorised discharge in the unlikely event that any previous control would have failed (e.g. discharge of the wrong tank which may have contained unusually elevated activity). In the event the pre-determined threshold is met, the final isolation valve will close preventing further discharge.

1245. The same level of monitoring is not required on the SEK discharge line considering the effluents received and discharged via this system are expected to be uncontaminated. Furthermore, monitoring undertaken at various points in the secondary circuit to detect primary to secondary leaks, and the monitoring of sumps and storage tanks before discharge means that if contamination was to be found in a tank or sump then its contents would be sent to the TEU for treatment and not sent to SEK. These factors mean that global gamma activity monitoring does not provide any additional environment protection and is therefore not required.

1246. The analytical equipment selected will provide representative results with appropriate limits of detection taking account of the European Commission's recommendations, international best practice and relevant standards, and in particular:

- MCERTS Performance standard for organisations undertaking radio analytical testing of environmental and waste waters.
- BS ISO 20042– Measurement of Radioactivity – Gamma ray emitting radionuclides – generic test method using gamma-ray spectrometry.
- BSI BS EN 60861 – Equipment for monitoring of radionuclides in liquid effluents and surface waters.
- BSI BS EN ISO/IEC 17025 – General requirements for the competence of testing and calibration laboratories.
- BSI BS ISO 11929– Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurement of ionising radiation – fundamentals and application.

1247. Each FPS fitted on the KER, TER and SEK discharge lines will comprise a flow meter which enables the sample taken to be proportional to the flow. In addition, a separate ultrasonic flow meter which will be MCERTS certified will be fitted to continuously measure flow rates during discharges, from which will be derived the volume of effluent discharged for reporting purposes.

1248. Level sensors will be fitted onto the KER, TER and SEK tanks. Effluent level readings will be taken on these tanks before and after each discharge. If the proportional sampler is inoperable the tank level measurements are available to provide a backup method of calculating the volume of effluent discharged.

1249. Each FPS will have an interlock that would allow the discharge to stop if the FPS is inoperable, allowing the operator to carry out detailed analysis on the tank samples if necessary to make the discharge and bypass the FPS. In that case (bypass of FPS), the tank level measurements and analysis of the tank samples would be used as the back-up method for statutory discharge reporting, until the FPS returns to service. The activity discharged will be assessed using the following method:

- The activity measured for each radionuclide or group of radionuclides will be expressed in Bq/m^3 or Bq/l:
    - If the measurement is above the limit of detection of the analytical instrument used, the actual measured value will be used.
    - If a radionuclide or group of radionuclides is measured at the limit of detection, the activity in the sample is considered as half the limit of detection unless it can de be demonstrated that the radionuclide or group of radionuclide measured cannot have been present in the discharge outlet in which case the activity is considered as null.
- The activity in Bq/m^3 or Bq/l is then multiplied to the volume of effluent discharged to obtain the activity discharged per tank.

- Each time a tank is discharged the activity discharged from this tank is added to the site rolling totals over 3 months and 12 months so they can be compared against the QNLs and annual limits, respectively.

6.5.7 Claim 5, Argument 26: Solid Waste Monitoring

1250. Monitoring of radioactive solid waste will ensure that BAT is applied to minimise the amount of radioactivity disposed of to the environment and the impact of such disposals on members of the public, and to minimise the volume of waste disposed to other premises.

6.5.8 Sub-Argument 31: Appropriate radioactive solid waste monitoring will be undertaken to determine the activity of solid waste transferred to other premises

1251. Solid waste monitoring includes:

- waste characterisation to establish the radioactive content of a waste stream; and,
- monitoring of final waste packages for sentencing to the appropriate disposal route or the HHI.

The application of BAT to solid radwaste monitoring is underpinned by:

- The ability, for each waste stream, to measure or calculate (as appropriate) all the radionuclides specified in the WAC of the expected disposal route(s), unless it can be demonstrated that certain radionuclides cannot be present in the waste stream by the nature of the process generating the waste.
- Representative sampling of the waste stream or an appropriate surrogate (e.g. effluents upstream of resin beds, surface smears etc.).
- Proportionality of the monitoring technique to the complexity and stability of the fingerprint.
- Adequacy of the monitoring technique to the radiological and physical homogeneity of the waste.
- Early characterisation and segregation (i.e. close to the point of generation) for optimised treatment and/or disposal.
- Minimisation of secondary waste (in volume) and/or discharges (in activity) SFAIRP.
- Appropriate operational and maintenance arrangements, in particular:
    - there is safe and easy access to sampling equipment for sampling and maintenance activities;
    - there is sufficient space for maintenance equipment and personnel;
    - appropriate radiological protection measures are provided;
    - monitoring equipment is protected from environmental conditions and personnel interference where needed (e.g. locks); and,
    - appropriate testing and calibration are undertaken.
- Appropriate analytical techniques including limits of detection limits below or equal to relevant limits in the relevant WAC.
- Background radiation levels are minimised where measurements are made.

- Confirmation of the non-radioactive properties of radioactive waste to ensure compliance with treatment/ disposal WAC.

a) Evidence 202: Arrangements for solid radioactive waste activity monitoring

1252. SZC Co. will implement processes for the management of solid radioactive waste that ensure compliance with the requirements of the RSR environmental permit and are proportionate to the environmental risk. Solid waste monitoring includes the full breadth of monitoring and sampling assessment from early in-process monitoring to inform decision making regarding the impact of operational activities on the generation of radioactive waste as well as final characterisation of waste to ensure they are correctly sentenced and disposed.

1253. These processes will cover all aspects of radioactive waste management. As part of these processes SZC Co. will adopt detailed and documented monitoring processes that provide measurement data to enable effective decision making and ensure that relevant operating conditions that underpin the monitoring strategy are identified and controlled.

1254. BAT will be implemented for the assessment of all solid radioactive waste streams to allow appropriate, consistent and traceable decisions to be made regarding the appropriate treatment, conditioning and sentencing of such wastes. SZC Co. will ensure realistic assessments are made for waste sentenced for disposal or transfer whilst minimising the risk that waste could be incorrectly classified. SZC Co. will ensure that all techniques remain appropriate, effective and that changes are adequately assessed, categorised and managed appropriately.

1255. Assessment is the use of all existing information about the nature, history of, and any measurements made on an article, substance or waste to permit decisions to be made regarding the treatment, conditioning, storage and sentencing of waste for disposal or transfer from the SZC Licensed Site. Measurements may include monitoring to determine the radionuclide content of waste and the determination of other metrics required for the assessment. Techniques will be developed for all solid waste streams treatment, conditioning, and storage.

1256. Further in-process monitoring is required for the sampling of solid waste. Sampling of solid waste (in-process) is used to characterise the radioactivity in order to determine the appropriate treatment, storage or disposal route. A number of reports have been completed to determine the BAT for solid waste sampling and characterisation:

1257. [Ref 203] Environmental Optimisation Study looking at EDF French fleet practice for the characterisation and assessment of spent APG resins justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1258. [Ref 204] Environmental Optimisation Study looking at EDF French fleet practice for the sampling and Measuring Activity of HEPA filters justifies the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1259. [Ref 205] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in charcoal filters/iodine traps justifies that main gamma emitters and the tritium content can be measured directly on activated carbon.

1260. [Ref 206] Environmental Optimisation Study looking at EDF French fleet practice for Characterisation of Radioactive Sludge justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1261. [Ref 207] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in Oils and Solvents justifies that as the ‘fingerprint and scaling factor’ approach is not applicable to characterise oils and solvents; the waste stream will be characterised by full destructive analysis:

- A representative sample of the de-watered and filtered waste stream will be retrieved from each drum.
- Samples will be analysed routinely by gamma spectroscopy and liquid scintillation techniques.
- In case of fuel cladding failure, a destructive analysis of alpha emitters will also be undertaken.

1262. [Ref 208] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in DAW and Metallic Waste from their generation to the final characterisation of the packaged waste. This report justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1263. [Ref 209] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in Active Resins justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1264. [Ref 210] Environmental Optimisation Study looking at EDF French fleet practice for Sampling and Measuring Activity in Concentrates presents the sampling and monitoring programme to be used to characterise the radioactivity of evaporator concentrates. This report justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1265. [Ref 211] Environmental Optimisation Study looking at EDF French fleet practice for Sampling and Measuring Activity in Water Filters justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

b) Evidence 203: Use of solid radioactive waste characterisation to select optimal treatment and disposal route

1266. Waste characterisation includes:

- Segregation at source to prevent cross-contamination and enable minimisation of the volume of radioactive solid waste generated and optimisation of solid waste disposal.
- Detailed measurements to establish the radionuclide breakdown of each waste stream - this is referred to as establishing the “fingerprint” for the waste stream. Fingerprints campaigns will be undertaken at SZC at an appropriate frequency. The frequency will be specific to each waste stream and dependent upon the stability of fingerprint and potential variations in the processes generating the waste stream.
- From the fingerprint, “scaling factors” can be established relating a radionuclide such as cobalt-60 to the proportions of other radionuclides in each waste stream. Once the first fingerprints are established and between two fingerprint campaigns, routine (less detailed) gamma measurements will be made to determine the waste stream content using scaling factors.

1267. If the fingerprint of a waste stream does not appear stable (e.g. ILW resins), the scaling factor method will not be used but instead each batch of waste will be fully characterised prior to the start of treatment of this batch.

1268. In some cases, the routine monitoring technique used to determine the waste activity using scaling factors will also serve as the segregation method when the segregation is based on activity.

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c) Evidence 204: Assessment of solid radioactive waste disposals to determine appropriate disposal route

1269. Waste packages will be monitored via appropriate methods e.g. drum monitors, to determine the activity contained in the final waste packages. The activity measured and the waste containers and conditioning process characteristics will be used to determine the volume and activity of waste is disposed of to waste service providers (LLW and VLLW) or HHI (ILW). In addition, characterisation data will be used to determine the radionuclide breakdown of the waste package. This will demonstrate compliance with Waste Acceptance Criteria or Letter of Compliance requirements as applicable.

6.5.9 Sub-Argument 32: Appropriate in-process monitoring is undertaken and optimised for solid wastes

1270. In-process monitoring is required for the sampling of solid waste. Sampling of solid waste is used to characterise the activity of wastes in order to determine the appropriate treatment, storage or disposal route.

a) Evidence 205: Arrangements for in-process monitoring of solid wastes

1271. A number of process parameters other than radionuclides or chemicals have the potential to influence the generation, storage treatment or disposal of radioactive solid waste. These parameters will be monitored using appropriate techniques. They include:

- checking of the position of waste containers and height of platform (in the case of evaporator concentrates and sludge) in the TES encapsulation cell to ensure correct functioning of the encapsulation process;
- measurements of the amount of grout, water and waste as well as the formulation of grout used in the TES encapsulation cell to ensure that the encapsulation process is optimised in terms of volume reduction, waste form stability and disposability;
- measurements of the amount of polymer, water, hardening agent and spent ion exchange resin in the MERCURE machine to ensure that the encapsulation process is optimised in terms of volume reduction, waste form stability and disposability;
- level measurements in the TES evaporator concentrate tanks to inform the need to empty tanks and timing of encapsulation campaigns;
- level measurements in the TES resin tanks to inform radiological protection requirements and timing of encapsulation campaigns;
- measurement of temperature in the TES evaporator concentrate tanks and in the TEU evaporator loop to prevent boron crystallisation;
- visual inspections and operability tests of the TES shredder and low force compactor to ensure they are operable and safe to use;
- visual inspections and operability tests of the TES filter change machine to ensure it is operable and safe to use, to minimise risks of filter damage and ensure a high degree of availability so that filters can be changed when needed; and,
- checks on waste packages stored in HHI to ensure the integrity of the packages is maintained.

b) Evidence 206: Optimisation of monitoring techniques used for solid wastes

1272. A number of studies referenced below justify the establishment of waste stream fingerprints and the use of a scaling factors approach based on BS ISO 21238:2007 as RGP for all wastes apart from oils and solvents at SZC. The justification is based on OEF from the approaches to characterisation in France and at SZB and other operators globally. It is based on the fact that Co-60 will be a dominant radionuclide for all waste streams at HPC. Specific details of how fingerprints will be established for each waste stream will be developed following the generation of wastes.

1273. [Ref 203] Environmental Optimisation Study looking at EDF French fleet practice for the characterisation and assessment of spent APG resins justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1274. [Ref 204] Environmental Optimisation Study looking at EDF French fleet practice for the sampling and Measuring Activity of HEPA filters justifies the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1275. [Ref 205] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in charcoal filters/iodine traps justifies that main gamma emitters and the tritium content can be measured directly on activated carbon.

1276. [Ref 206] Environmental Optimisation Study looking at EDF French fleet practice for Characterisation of Radioactive Sludge justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1277. [Ref 207] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in Oils and Solvents justifies that as the ‘fingerprint and scaling factor’ approach is not applicable to characterise oils and solvents; the waste stream will be characterised by full destructive analysis. A representative sample of the de-watered and filtered waste stream will be retrieved from each drum, samples will be analysed routinely by gamma spectroscopy and liquid scintillation techniques. In the case of fuel cladding failure, a destructive analysis of alpha emitters will also be undertaken.

1278. [Ref 208] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in DAW and Metallic Waste from their generation to the final characterisation of the packaged waste. This report justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1279. [Ref 209] Environmental Optimisation Study looking at EDF French fleet practice for Measuring Activity in Active Resins justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1280. [Ref 210] Environmental Optimisation Study looking at EDF French fleet practice for Sampling and Measuring Activity in Concentrates presents the sampling and monitoring programme to be used to characterise the radioactivity of evaporator concentrates. This report justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

1281. [Ref 211] Environmental Optimisation Study looking at EDF French fleet practice for Sampling and Measuring Activity in Water Filters justifies that the 'scaling' methodology is appropriate for wastes generated from an UK EPR^{TM}, such as SZC.

6.5.10 Claim 5, Argument 27: Use of appropriate plant condition monitoring techniques

1282. Appropriate monitoring will be undertaken for the assessment of, performance of and trending of activity in, systems or components that are involved in the generation, storage or treatment of radioactive effluents. Use of techniques will be optimised where this represents BAT to ensure the most appropriate options are used for each waste stream.

a) Evidence 207: Use of radiochemical in-process monitoring techniques

1283. Radiochemical monitoring will be undertaken in the relevant systems from the point of generation (e.g. RCP, HK spent fuel pool) through to the various stages of storage and treatment prior to final storage and discharge (e.g. RCV, TEP, TEG, TEU).

1284. The application of BAT for in-process radiochemical monitoring is underpinned by:

- Monitoring of appropriate radionuclides in the relevant systems, at an appropriate frequency and in the appropriate plant states.

- Consistency with relevant national and international standards.
- Consistency with regulatory and industry guidance and codes of practice.
- Appropriate location of sampling points and on-line monitors.
- Appropriate design of the sampling line to ensure representative sampling.
- Appropriate sampling technique to ensure representative sampling, compatibility with the analytical technique, and appropriate calibration, testing and maintenance arrangements.
- Appropriate on-line monitoring techniques (including limits of detection) to ensure representative measurements and appropriate calibration, testing and maintenance arrangements.
- Appropriate analytical techniques (including limits of detection) to ensure representative measurements and appropriate calibration, testing and maintenance arrangements.
- Safe and easy access to sampling and on-line monitoring equipment and sufficient space for maintenance equipment and personnel.
- Appropriate maintenance and testing arrangements for sampling, on-line monitoring and analytical equipment.

b) Evidence 208: Use of chemical in-process monitoring techniques

1285. Chemicals that are at the origin of the radioactive source term will be monitored to provide trending information on the radioactive source term and to assess the influence of these chemicals on the radioactive source term. Boron and lithium will be monitored to assess the tritium source term in the primary coolant. Nitrogen will be monitored in the primary coolant to assess the carbon-14 source term.

1286. The application of BAT for in-process chemical monitoring is underpinned by:

- Monitoring of appropriate chemicals in the relevant systems, at an appropriate frequency and in the appropriate plant states.
- Appropriate location of sampling points or on-line monitors in these systems.
- Appropriate design of the sampling line to ensure representative sampling.
- Safe and easy access to sampling and on-line monitoring equipment.
- Appropriate sampling technique to ensure representative sampling, compatibility with the analytical technique, and appropriate calibration, testing and maintenance arrangements.
- Appropriate on-line monitoring techniques to ensure representative measurements and appropriate calibration, testing and maintenance arrangements.
- Appropriate analytical techniques to ensure representative measurements and appropriate calibration, testing and maintenance arrangements.

c) Evidence 209: Use of plant condition process monitoring techniques

1287. A number of process parameters other than radionuclides or chemicals have the potential to influence the generation, storage, treatment or disposal of radioactive liquid and gaseous effluents. These parameters will be monitored using appropriate techniques. They include:

- Measurement of relevant parameters in and/or around the fuel pools of the HK, HR and in the IRWST, to assess the tritium evaporative losses coming from these storage pools/tank, based on the tritium inventory in the liquid phase informed by liquid phase sampling. Relevant parameters include ambient and pool temperature, relative humidity and ventilation flow rates in DWK and EBA. This will be more representative than trying to monitor tritium in the atmosphere of the HK and HR buildings.

- Measurement of water levels in fuel pools in HK and HR, and in the IRWST, to inform needs to water make up and detect major leaks.
- Leak detection of sumps, pool and tank liners.
- Measurement of tank levels to indicate system leakage or other issue (e.g. risk of overflow) and provide OEF e.g. rate at which tanks are filling.
- Measurement of parameters such as flow-rate, pressure, temperature and purity of purge gas in sampling lines to ensure representative sampling / on-line measurements.
- Differential pressure measurements on HEPA filters and iodine traps to determine when a filter needs to change.
- Measurement of the differential pressure of water filters and flow rates passing through the filters used in the treatment systems RCV, TEP, TEU, PTR, APG, RPE and SBE. These measurements will be used to ensure good performance of the filters and indicate when they need to be changed.
- Measurement of temperature at the inlet of demineralisation beds used in the treatment systems RCV, TEP, TEU, PTR and APG. These measurements will be used to ensure the good performance of the ion exchange resins.
- Visual inspection of oil separators in SEK to check for clogging.

d) Evidence 210: Consideration of optimisation for monitoring techniques

1288. The expected RSR permit for the disposal of radioactive waste from Sizewell Point C will require the operator to demonstrate that BAT has been applied.

1289. In order to demonstrate compliance with the conditions of the permit, NNB GenCo (HPC) has produced EOS reports in order to provide specific assessments related to the monitoring of aqueous and gaseous effluents and solid waste. EOS reports are detailed in waste stream specific evidence for gaseous [Evidence 164], liquid [Evidence 167] and solid waste [Evidence 169].

1290. The basic design of the UK EPR^{TM} was established in the GDA process and based on the Flamanville 3 (FA3) EPR^{TM}, which is the starting point for BAT assessments. The UK EPR^{TM} is an evolutionary design based on a large amount of OEF and good engineering, therefore undertaking a full optioneering of the entire design is regarded as a disproportionate use of resources compared to the potential gain in BAT.

1291. The EOS reports include a description of the BAT Assessment criteria used and each report includes sections on sampling techniques. It is not considered that the EOS reports consider any part of the design from HPC that will not be consistent for SZC, and therefore their contents are considered wholly applicable.

e) Evidence 211: Efficiency Testing of HEPA filtration and Iodine adsorption units

1292. Each of the systems DWN, 9DWQ and EBA, have HEPA filtration and Iodine trap facility however the layouts of each system vary considerably. It is necessary to ensure that the efficiency of filtration systems can be verified in-situ. An assessment was produced [Ref 141] to determine BAT to ensure robust and reliable testing of HEPA filters and Iodine traps as part of the in process monitoring on the DWN, 9DWQ and EBA's.

1293. A number of technologies exist to verify the performance of HEPA filters such as DOP Dispersed Oil Particle (DOP) testing and Condensation Nuclei (CN), along with other specific methods for Iodine trap testing. It has been determined that both DOP and CN testing are BAT [Ref 21] however DOP testing has been adopted for HPC testing of HEPA filters due to standardisation with EDF Energy fleet and UK practice.

1294. Iodine trap testing also requires the injection of challenge material. A BAT assessment was produced to demonstrate that the specification for the charcoal and charcoal challenge material for the Iodine filtration units represents BAT [Ref 130]. From this assessment a charcoal with the characteristic similar to charcoal sourced from coconut shells, impregnated with either 1% Potassium Iodide (KI) or 2-5% Triethylenediamine (TEDA) is considered to be the option that demonstrates BAT, provided that the requirement of 99% efficiency is met. A non-powdered charcoal should be selected, in order to minimise dust generation. OEF from the EDF Energy Nuclear Generation fleet is that the charcoal should be virgin material, re-activated or re-impregnated material should not be used. These requirements are to be incorporated into procurement specifications for the SZC project, without specifying the exact charcoal type, so as not to foreclose options.

1295. HEPA filters can be tested both individually or grouped (as casings within a bank) and the report demonstrates that by providing upstream and downstream sample points for both sampling arrangements will minimise maintenance and operator burden, wastage generation and disposal, whilst ensuring that filter efficiency can be tested.

1296. To ensure that complete mixing of any challenge material injected into the system, whether for HEPA filter or Iodine Trap testing, a number of options were considered. It has been demonstrated that the minimum distance of 30D of straight duct required for single injection without any additional aids is not possible for DWN and DWQ as the layout changes to both systems and building footprint are grossly disproportionate to the benefit where other options can be used. It is however possible that the intended design for EBA will meet this requirement for most injection/sample points.

1297. The use of mixing devices (compressed air or mixing blade) can be used however it has been deemed that by applying the EDF specification for testing on the existing UK fleet, and selecting a suitable injection nozzle and sampling configuration, mixing can be achieved without incurring excessive waste, energy usage or additional maintenance costs and therefore the use of a multi array nozzle for injection and sampling is BAT to ensure robust and reliable testing of both HEPA filters and Iodine Traps [Ref 141].

1298. The type of multi-array nozzle is determined by applying guidance in the EDF Energy specification – with the number and arrangements of injection/sampling nozzles determined based on the flow rate and the maximum achievable distance to the sampling point.

1299. The final configuration of all systems is presented in Appendix 7 of [Ref 141] however it must be noted that the positioning of injection and sample points is based on the maximum distance achievable with the current layout.

1300. The EDF Energy specification requires testing to be undertaken as part of acceptance into service, and from then either biennially (with a maximum period of 28 months) or on replacement. It is expected that testing will be undertaken as part of commissioning to accept the first set of filters into service, however any additional testing to be undertaken as part of commissioning is still to be determined.

f) Evidence 212: In-process monitoring to minimise the impact of the use of Hydrazine in aqueous discharges

1301. Hydrazine will be used at SZC subject to conditions in the Water Discharge Activity (WDA) permit. To ensure compliance with the permit, measures need to be taken to both measure the levels of hydrazine in effluent within the KER, TER and SEK's in order to determine the appropriate level of treatment prior to discharge and to ensure that as per the WDA Commitment Plan on hydrazine, the level of hydrazine measured in waste streams shall be below the Limit of Detection of the selected analytical method. The BAT assessment [Ref 212] demonstrates the justification for the selection of spectrophotometric determination with p-dimethylaminobenzaldehyde.

1302. As no further abatement is routinely employed (tap off filtration may be available) this has the potential to impact the RSR requirements to minimise discharges of particulate matter and also to ensure representative sampling. The BAT assessment [Ref 219] presents this risk, demonstrating why it is important to minimise the use of hydrazine.

g) Evidence 213: Maintenance and Reliability

1303. Advanced Process (AP) 913 is an equipment reliability process established by the Institute for Nuclear Power Operation. This process forms part of the Maintenance Strategy for the SZC project, and assists utilities in maintaining high levels of safe and reliable plant operation in an efficient manner.

1304. The objective of the AP913 process implementation in Design phase is to improve the design by reducing the Single Point Vulnerability components and to establish an appropriate Initial Preventive Maintenance Strategy focused on the most critical components and on their failure mitigation. AP913 is considered an industry wide good practice, and its application is considered sufficient to ensure reliability of monitoring arrangements implemented on the SZC project.

1305. Specific requirements to demonstrate reliability of the equipment as part of commissioning will be addressed in the SZC permit application head document [Ref 1] forward action plan.

6.5.11 Claim 5, Argument 28: Appropriate environmental monitoring will be undertaken to assess the impact of radioactive disposals on the environment and members of the public

1306. Environmental monitoring is required to be undertaken by SZC Co. to demonstrate compliance with the RSR permit for SZC. This is usually started in a period around construction of the site and as such, detailed information on how SZC Co. will undertake environmental monitoring will be developed in time, through development of an Environment Radioactivity Monitoring Strategy (ERMS).

1307. Environmental monitoring will be undertaken to ensure that:

- there is a coherent environmental monitoring strategy in place;
- the relevant monitoring, sampling, analysis and assessment are BAT (in terms of what is being assessed, the frequency, the method and the analysis); and,
- appropriate arrangements are in place for the analysis of samples if not undertaken in house.

1308. SZC Co. will seek agreement of the monitoring objectives for the programme from relevant stakeholders, including the EA. The arrangements will be formalised with the regulator prior to implementation. The programme will be subject to a timely review process to ensure it remains fit for purpose. This approach accords with the process proposed in the environment agency’s guidance. Importantly the approach needs to take account of the principles presented in the environment agency’s guidance, notably the need to be proportionate, complementary and optimised.

1309. SZC Co. will use OEF from development of the HPC ERMS [Ref 213] and, will align to the EDF fleet wide approach for elements of the strategy relating to procedural and operational components, while taking into account any learning from experience gained from the approvals and implementation process from HPC. Development of the Environmental Monitoring programme for SZC is covered in the forward action plan in the SZC RSR Permit application head document [Ref 1].

1310. Environmental monitoring will be undertaken through delivery of the environmental monitoring strategy implemented into the environmental monitoring programme, which will specify what will be monitored, where, when and how.

1311. Key aspects include:

- Selection of appropriate sampling or monitoring locations, sample media and frequencies.
- Use of representative sampling or monitoring techniques.
- Monitoring and/or analysis of appropriate radionuclides or groups of radionuclides.
- Use of appropriate laboratory analysis techniques consistent with relevant standards and MCERTS, if applicable.

1312. The following evidence demonstrate the key elements of the ERMS, further details will become available as the details of the strategy are completed and agreed with the relevant stakeholders/regulators.

a) Evidence 214: Use of an environmental sampling strategy

1313. The ERMS and subsequent detailed environmental monitoring programme for SZC will be developed to ensure it is optimised and proportionate in line with regulatory guidance [Ref 214]. The environmental agencies joint guidance outlines a process for designing an Environmental Monitoring Programme.

1314. SZC Co.'s process is:

- establish monitoring objectives;
- determine what to monitor / sample;
- where and when to sample; and,
- how to sample.

b) Evidence 215: The location of environmental sampling points is appropriate

1315. Environmental monitoring and sampling will be required in the locality of SZC to monitor any effects and impacts on the environment, biota and human population as a result of radioactive discharges from operations. Sampling locations will be considered as part of the development of the ERMS to best demonstrate the impacts around SZC.

c) Evidence 216: The timing and frequency of environmental sampling is appropriate

1316. Environmental sampling will be required year round to ensure all impacts from operations are considered. However, the timing and frequency of sampling may vary depending on the media being sampled, the population being considered and the stage of the facility lifecycle (i.e. commissioning, operations, decommissioning). The ERMS will consider the requirements for SZC in accordance with best practice and regulatory guidance.

d) Evidence 217: Environmental sampling, monitoring and analytical techniques and equipment is appropriate

1317. The type of sampling and monitoring technique and equipment is dependent on the objectives of the monitoring plan, what environment or population is being monitored, what types of radionuclides are appropriate (to show compliance with the RSR permit and/or international obligations) and the timing of analysis for each group of radionuclides (i.e. taking into consideration half-life decay of short lived species). Appropriate techniques and equipment will be selected and BAT justified, and recorded in the ERMS for each type of monitoring required, to ensure use of best practice and compliance with regulatory guidelines.

e) Evidence 218: Assessment of environmental sampling data is completed and appropriate

1318. Data collected during the environmental monitoring programme will be assessed using appropriate techniques to meet the objectives, as defined by the ERMS. This will include annual retrospective assessments of the dose to the representative person.

1319. Key aspects include:

- identification of representative person and definition of habit data; and,
- use of appropriate dose assessment methodology based on environmental monitoring data.

f) Evidence 219: Recording of environmental sampling data is completed and appropriate

1320. Reporting of the environmental monitoring data and outcome of analysis is a key component of demonstrating compliance with the RSR permit requirements. The ERMS will consider and detail the methods for ensuring training of Suitably Qualified and Experienced Personnel operators for monitoring, sampling and analysis roles and will ensure procedures are identified and implemented for verification of data and interfacing with regulators for the delivery of relevant data records.

7 Forward Work Plan

1321. The information in this support document provides appropriate information on the application of environmental optimisation at SZC for the current stage of development. Forward actions identified in Section 6 will be captured and managed via the open point register [Ref 16] as set out in section 3.3. Where appropriate above it has been noted where specific issues are already captured via an open point as part of normal business. It is recognised throughout this RSR application that learning will be taken where possible from the Hinkley Point C project and adopted, as appropriate, to SZC. The current open points, commitments and RSR Information Conditions owned by HPC will be reviewed at the appropriate time for applicability to SZC, this is captured as part of normal business in [SZC RSR CMT1] for the SZC RSR permit application [Ref 1].

8 Conclusions

1322. The practice of generating electricity from 2 UK EPR^{TM} units at SZC is considered to be optimised at this stage of the project and demonstrates that environmental optimisation through the application of BAT is being applied to:

- Claim 1: SZC Co. Shall Eliminate or Reduce the Generation of Radioactive Waste.
- Claim 2: SZC Co. Shall Minimise the Amount of Radioactivity Discharged or Disposed of to the Environment.
- Claim 3: SZC Co. Shall Minimise the Volume of Radioactive Waste Disposed to Other Premises.
- Claim 4: SZC Co. Shall Minimise the Impacts on the Environment and Members of the Public from Radioactive Waste that is Discharged or Disposed of to the Environment.
- Claim 5: SZC Co. shall undertake appropriate monitoring to check compliance with the conditions of the RSR permit.

1323. It is recognised that the demonstration of BAT within the Environment Case builds upon the existing environment case that was established in the HPC RSR Permit Application, and it has been demonstrated in section 3 that the work taken credit for has been assessed to confirm its relevance for the SZC project, and reviewed and updated to reflect the baseline SZC design.

1324. The evolutionary nature of the UK EPR^{TM} has focused on eliminating as much of the radioactive waste at source as possible. Where elimination is not practicable efforts have been made to reduce the activity and quantity of radioactivity associated with the waste. Waste that is not created does not need management or discharge/disposal. This is consistent with the waste hierarchy and is considered to be the most effective means of protecting the environment and members of the public. Taken together it is claimed that the features described Claim 1 and 2 are expected to eliminate or reduce the generation of radioactive waste and will, therefore, make a significant contribution to minimising the activity of the waste that will be discharged or disposed of.

1325. Radioactive waste will be created during the operation of SZC. Efforts have been expended to develop or select equipment and systems that reduce the amount of radioactivity that will be disposed of to the atmosphere or to the sea. The selection of equipment and systems has taken account of operational experience and feedback gained from reactors around the world and from the development and permitting consultation of the HPC sister site development. Where appropriate, a range of meaningful alternatives have been considered. Taken together the features described in Section 6 are expected to minimise the activity of the radioactive waste that is discharged to the environment and to promote the exclusion of entrained matter in aqueous discharges. This will further reduce the radioactive discharges from SZC and the associated impacts to the environment and members of the public.

1326. The principle of ‘concentrate and contain’ encourages disposing of radioactivity in a concentrated, solid form in preference to dilution and dispersion in the environment. The UK EPR^{TM} has evolved to employ features that will concentrate the radioactivity of the wastes and reduce the volume of solid waste that will eventually require disposal. It is important to recognise that some of the solid waste disposal options that will be used support the delivery of the ‘concentrate and contain’ principle. An optimal balance between activities undertaken at SZC and the benefits from selected waste treatment options must therefore be sought. Taken together the techniques described in Section 6 will make the most efficient use of the waste management infrastructure; minimise the quantity of secondary waste that is produced; and reduce pressure on current and future waste disposal facilities. They will reduce the volume of waste that will be disposed to other premises.

1327. The design of SZC includes a range of features that promote the effective partitioning and dispersion of radioactivity in the environment. Taken together the proposed techniques are expected to demonstrate that the impacts on the environment and members of the public from unavoidable discharges are ALARP.

1328. In order to demonstrate the totality of the case for environmental optimisation it is the aggregation of these claims and corresponding arguments that must be considered together.

1329. Rightly, there is an emphasis on minimising the radioactivity produced in the first place. The avoidance of generating waste by reducing the waste at source is a critical element of the case for optimisation. It is particularly important in the early stages of a project as there are significant opportunities afforded that, if missed would be technically difficult or disproportionably costly (in terms of time, resources and money). Given that the SZC project builds upon design work undertaken since the HPC permit application, it is acknowledged that at this point in the process the design is well established and opportunities for further optimisation are limited and required to be consistent with the replication strategy.

1330. It is recognised that as the project progresses through different phases the emphasis placed on the different arguments may change. Effectively some of the techniques applied can be “banked”, however these should not be ignored as they still form an inherent part of the case. For example, once the reactor has been constructed the cobalt specification of the reactor is likely to play a less significantly role in the case for optimisation as focus moves to arguments relating to commissioning and operational management practices. Our methodology reflects the evolving nature of environmental optimisation. Key arguments that are relevant to this stage of the project are:

- Specification of materials of construction for the reactor and cooling circuits to reduce the generation of radioactive waste that will require disposal.

- Efficiency of fuel use during operations to minimise the amount of spent nuclear fuel that will require disposal.
- Engineered containment systems to limit the spread of radioactivity and the consequent generation of waste that will require disposal.
- Primary Coolant chemistry to minimise the generation of radioactivity directly and indirectly though corrosion control.
- Decay storage of wastes to reduce the radioactivity associated with wastes that will require disposal.

1331. Therefore, when taking the case in its entirety, including those elements reflected in the Forward Action Plan, SZC Co. consider that the arguments presented, when considered together, demonstrate that environmental optimisation is being delivered through the application of BAT.

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