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ASSESSMENT REPORT

Civil Nuclear Reactors Programme

NNB GenCo: Hinkley Point C Pre-Construction Safety Report 2012 – Assessment Report for Work Stream B13 – Reactor Chemistry

Assessment Report: ONR-CNRP-AR-13-085
Revision 0
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EXECUTIVE SUMMARY

This assessment report (AR) reviews that portion of the Hinkley Point C Pre-Construction Safety Report 2012 (HPC PCSR2012) that falls within the scope of Work Stream B13 – reactor chemistry. There is no single chapter, or sub-chapter, of the HPC PCSR2012 that contains all of the information relevant to this assessment. Most of the information assessed was contained within sub-chapters 5.5, 6.9, 9.6 and 10.7 which cover reactor, safeguard and containment, auxiliary and secondary circuit system chemistry respectively. Additional chapters also contain other relevant information which formed part of this assessment, including source terms and operating limits and conditions. A total of 12 new sub-chapters were assessed, plus the head document and forward work activities report.

A final version of the Generic Design Assessment (GDA) Pre-Construction Safety Report (PCSR) issued in November 2012 formed the basis for issue by ONR on 13 December 2012 of a Design Acceptance Confirmation (DAC) for the UK EPR™ design. The GDA PCSR addressed only the key elements of the design of a single UK EPR™ unit (the generic features on “the nuclear island”) and excluded ancillary installations that a potential purchaser of the design could choose after taking the site location into account. Certain matters were also deemed to be outside the scope of the GDA PCSR.

In contrast HPC PCSR2012 addresses the whole Hinkley Point C licensed site comprising the proposed twin UK EPR units and all ancillary installations. Some matters that were outside the scope of GDA PCSR are also addressed in HPC PCSR2012. The reactor chemistry aspects of HPC PCSR2012 are a mixture of new information and information derived from the GDA process. In some instances the GDA information was taken directly from the March 2011 GDA PCSR, in other cases it was distilled from the final consolidated GDA PCSR from November 2012 or reports produced to resolve GDA Issues for UK EPR™. This assessment has therefore focused on those parts of HPC PCSR2012 that have changed from the March 2011 GDA PCSR, as this represents a baseline level of information that ONR has previously assessed.

It is important to note that HPC PCSR2012 alone is not sufficient to inform a future ONR decision on whether to permission construction of Hinkley Point C. NNB GenCo intends to submit a major revision to HPC PCSR2012 before seeking consent for Nuclear Island construction which will fully integrate the final GDA PCSR and will be supported by other documentation.

My assessment has highlighted the proactive approach taken by NNB GenCo in developing the chemistry aspects of HPC PCSR2012. This is significantly different from that taken during GDA, involving a more systematic review and definition of the chemistry requirements for the various plant systems and I judge this to be a positive improvement which will help in developing the safety case going forward. However, my assessment has highlighted that there is a level of inconsistency between the various chemistry sub-chapters, both in terms of quality and approach. Those which are based closely on the March 2011 GDA PCSR (namely sub-chapters 5.5. and 10.7) are much better than those which are new for HPC PCSR2012 (sub-chapters 6.9 and 9.6), although all sub-chapters are in need of improvement to some degree.

I conclude that sub-chapter 9.6 is currently inadequate as presented. Sub-chapter 6.9 also need significant development. I have raised this matter as an issue within ONR’s issues database, and will be covered through routine future regulatory work. This issue requires NNB GenCo to address these deficiencies and ensure that the consistency, visibility and clarity of chemistry related claims, arguments and evidence (or equivalent) is adequate.

However, I believe that the basis of an adequate safety case is present in the documents, but the presentation of it is poor at present. I am content that there are no fundamental safety issues or concerns, which are not covered by existing Assessment Findings from GDA of UK EPR™. I have raised an issue within ONR's issues database to address a site specific matter related to the demineralised water systems at HPC. At present the site specific aspects of HPC have made little difference to the principal chemistry elements of the safety case, which is as I would expect at this stage and will allow NNB GenCo to make best use of fleet standardisation with EDF and other EPR reactors worldwide.

In terms of development of the safety case for HPC, aside from the developments expected as part of normal business by NNB GenCo (including incorporation of the final consolidated GDA PCSR (November 2012), resolution of GDA Assessment Findings and design development), the key expectations that this assessment has highlighted are related to limits and conditions, chemistry control during transient periods, the development of secondary circuit chemistry and controls for boron. A number of GDA Assessment Findings already refer to these aspects.

To conclude, I am broadly satisfied with the claims, arguments and evidence laid down within the Licensee's safety case at this stage in the development of the design and safety case for HPC. However, I expect significant improvements to be made to the safety case at the next revision. In the longer term I would expect further refinements as the safety case moves towards commissioning and operations, where operational chemistry becomes more significant. I am content that the progress made by NNB GenCo in the reactor chemistry area supports the conclusion that these should be realised.

LIST OF ABBREVIATIONS

AAD [SSS]	Start-up and Shutdown Feedwater System
ABP	Low Pressure Feedwater and Heater System
ADG	Feedwater Tank and Gas Stripper System
AF	Assessment Finding
AHP	High and Medium Pressure Feedwater Plant and Heater System
ALARP	As Low As Reasonably Practicable
APG [SGBS]	Steam Generator Blow Down System
ARE [MFWS]	Main Feedwater System
ASG [EFWS]	Emergency Feedwater System
BAT	Best Available Techniques
BMS	(ONR) How2 Business Management System
CFI [CWFS]	Circulation Water Filtration System
CMSS	Core Melt Stabilisation System
CRF	Circulating Water System (or main cooling system)
DAC	Design Acceptance Confirmation
DEL	Safety Chilled Water System
DER	Operational Chilled Water System
DWK [FBVS]	Fuel Building Ventilation System
DWN [NABVS]	Nuclear Auxiliary Building Ventilation System
EA	Environment Agency
EBA [CSVS]	Containment Sweep Ventilation System
EDE [AVS]	Annulus Ventilation System
EDF SA	Electricité de France Société Anonyme
EPP	Leak Rate Control and Testing System
EPRI	Electric Power Research Institute
ETY [CGCS]	Combustible Gas Control System
EVR [CCVS]	Continuous Containment Ventilation System
EVU [CHRS]	Containment Heat Removal System
FA3	Flamanville 3
GCT [MSB]	Main Steam Bypass
GDA	Generic Design Assessment
HPC	Hinkley Point C
HPC PCSR2012	Hinkley Point C Pre-Construction Safety Report 2012
HSE	Health and Safety Executive

LIST OF ABBREVIATIONS

HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IRWST	In-Reactor Water Storage Tanks
ISFS	Interim Spent Fuel Store
JAC [FFWSS]	Fire Fighting Water Supply System
KRT [PRMS]	Plant Radiation Monitoring System
NNB GenCo	Nuclear New Build Generation Company
NSSS	Nuclear Steam Supply System
ONR	Office for Nuclear Regulation (an Agency of HSE)
OSC	Operational Service Centre
OTS	Operating Technical Specifications
PCSR	Pre-Construction Safety Report
PTR [FPPS/FPCS]	Fuel Pool Purification (and Cooling) System
RBS [EBS]	Extra Boration System
RCP [RCS]	Reactor Coolant System
RCV [CVCS]	Chemical and Volume Control System
REA [RBWMS]	Reactor Boron and Water Make-up System
REN [NSS]	Nuclear Sampling System
RIS [SIS]	Safety Injection System
RIS/RRA [SIS/RHRS]	Safety Injection System operating in Residual Heat Removal Mode
RPE [NVDS]	Nuclear Vent and Drain System
RRA [RHRS]	Residual Heat Removal System
RRI [CCWS]	Component Cooling Water System
SAP	Safety Assessment Principle(s) (HSE)
SDA [DPS]	Demineralised Production System
SEC [ESWS]	Essential Service Water System
SED [NIDWDS]	Nuclear Island Demineralised Water Distribution System
SER [CIDWDS]	Conventional Island Demineralised Water Distribution System
SFP	Spent Fuel Pool
SIR	Chemical Conditioning (Injection with Reagent)
SIT	Chemical Sampling and Monitoring System
SRU [UCWS]	Ultimate Cooling Water System
TAG	Technical Assessment Guide(s) (HSE)
TEG [GWPS]	Gaseous Waste Processing System
TEP [CSTS]	Coolant Storage and Treatment System

LIST OF ABBREVIATIONS

TEU [LWPS]	Liquid Waste Processing System
VGB	German Federation of Large Power Station Operators (VGB Powertech)
VVP [MSSS]	Main Steam Supply System
WENRA	Western European Nuclear Regulators’ Association

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1 INTRODUCTION

1.1 Background

1 This report presents the findings of the assessment of that portion of the Hinkley Point C Pre-Construction Safety Report 2012 (HPC PCSR2012, Ref. 1) that falls within the scope of Work Stream B13 – reactor chemistry.

2 Assessment was undertaken in accordance with the requirements of the Office for Nuclear Regulation (ONR) How2 Business Management System (BMS) procedure AST/003 (Ref. 2). The ONR Safety Assessment Principles (SAP), Ref. 3, together with supporting Technical Assessment Guides (TAGs), Ref. 4, have been used as the basis for this assessment.

3 This Assessment Report (AR) has been written to support a summary assessment report that addresses whether the extant safety case (known as HPC PCSR2012) demonstrates suitable progress towards meeting ONR's requirement for an adequate Pre-Construction Safety Report (PCSR) for Hinkley Point C (HPC). To this end this AR provides guidance on matters that need to be addressed in the next revision of HPC PCSR and beyond and, where appropriate, issues have been raised within ONR's issues database for resolution as part of future regulatory interactions.

1.2 Scope

1.2.1 Definition of Reactor Chemistry

4 The scope of this report covers Work Stream B13 – reactor chemistry. Reactor chemistry is a broad topic covering:

- any requirement or constraint placed on the operating chemistry of the plant which must be met in order to allow the plant to be operated safely;
- any chemistry related functional requirement which must be met to ensure that the plant is operated within its design basis; and
- any effect or consequence of chemistry which must be controlled in order to ensure safety including during normal operations, during faults or during severe accidents.

1.2.2 Hinkley Point C Safety Report

5 As reactor chemistry is a broad topic which affects multiple systems throughout the Hinkley Point C (HPC) plant design there is therefore no single chapter, or sub-chapter, of the HPC PCSR2012 that contains all of the information relevant to this assessment. Most of the information lies in sub-chapters 5.5, 6.9, 9.6 and 10.7 which cover reactor, safeguard and containment, auxiliary and secondary circuit systems respectively. Additional chapters also contain other relevant information which formed part of this assessment including on source terms and operating limits and conditions. Further details of the individual sub-chapters of the HPC PCSR2012 that formed part of this assessment can be found in Section 3 of this AR, and are detailed in Table 1.

6 HPC PCSR2012 is a mixture of new information and information derived from the GDA process. It is important to understand the status and development for this report, as this forms an important constraint to the present assessment.

7 A final version of the Generic Design Assessment (GDA) Pre-Construction Safety Report (PCSR) issued in November 2012 formed the basis for issue by ONR on 13 December 2012 of a Design Acceptance Confirmation (DAC) for the UK EPR design. The GDA PCSR addressed only the key elements of the design of a single UK EPR unit (the generic features on “the nuclear island”) and excluded ancillary installations that a potential purchaser of the design could choose after taking the site location into account. Certain matters were also deemed to be outside the scope of the GDA PCSR.

8 In contrast HPC PCSR2012 addresses the whole Hinkley Point C (HPC) licensed site comprising the proposed twin UK EPR units and all ancillary installations. Some matters that were outside the scope of GDA PCSR are addressed in HPC PCSR2012. As the generic features were addressed in the GDA process, attention has been concentrated here on site-specific documentation that has not been formally assessed by ONR previously. The remaining, generic documentation has been copied into HPC PCSR2012 from an earlier March 2011 GDA PCSR but this has now been superseded by the November 2012 GDA report. The generic documentation has only been revisited as part of this present assessment if recent developments have materially affected the case being made. This is described further in Section 4.2.1 of my report.

9 It is important to note that HPC PCSR2012 alone is not sufficient to inform a future ONR decision on whether to permission construction of Hinkley Point C and NNB Genco intends to submit other supporting documentation. Note also that HPC PCSR2012 will be superseded by a further site-specific revision intended to fully reflect the final GDA PCSR and other design changes from Flamanville 3 which is the reference design for HPC.

10 It should also be noted that the approach to safety function categorisation and safety system classification agreed during GDA is not fully reflected in HPC PCSR2012 which largely uses the approach employed on Flamanville 3 (FA3). The integration of the methodology agreed during GDA will be demonstrated in the next revision of the HPC PCSR.

1.3 Methodology

11 The methodology for the assessment follows the requirements of the ONR BMS ‘produce assessments’ step in the nuclear safety permissioning process and Ref. 3 in particular in relation to mechanics of assessment.

12 As described above, this assessment has focussed on the submissions given in Ref. 1 relating to reactor chemistry. The HPC PCSR2012 (presented in Ref. 1) is a mixture of information contained in the GDA March 2011 PCSR, either directly copied or updated, as well as additional site specific information. It is important to stress that information which was directly copied from the GDA March 2011 PCSR has already been assessed by ONR (as part of GDA) and has therefore not been reassessed (unless new information suggested that this was necessary). Other remaining relevant information in the HPC PCSR2012 formed part of this assessment. The assessment was also supplemented with additional information reviewed as part of on-going interventions with NNB GenCo on reactor chemistry. This includes the development of resolution plans for Assessment Findings (AFs) raised during GDA for the generic UK EPR™ design.

13 This assessment allows ONR to come to a judgement on whether the NNB submissions in the area of reactor chemistry provide evidence that adequate progress is being made in the development of a PCSR to support construction of a UK EPR™ at HPC.

2 ASSESSMENT STRATEGY

14 My assessment strategy is set out in this section. This identifies the scope of the assessment and the standards and criteria that have been applied.

2.1 Standards and Criteria

15 The relevant standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAPs), Ref. 3, internal ONR Technical Assessment Guides (TAGs), Ref. 4, relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites. The key SAPs and relevant TAGs are detailed within this section. National and international standards and guidance have been referenced where appropriate within the assessment report. Relevant good practice, where applicable, has also been cited within the body of the assessment.

2.1.1 Safety Assessment Principles

16 The key SAPs applied within the assessment are included within Table 2 of this report. These SAPs are focussed on the functions and systems leading to the largest hazards or risk reduction and are similar to those considered throughout the previous GDA assessments of the UK EPR™ generic design.

2.1.2 Technical Assessment Guides

17 The TAGs (Ref. 3) listed in Table 3 have been used as part of the assessment. These are those that relate to the SAPs identified in Section 2.1.1, above.

18 In addition, ONR has produced a reactor chemistry specific TAG. This was produced during 2013 and was undergoing final approvals, prior to publication, at the time of preparing this assessment report. It is likely the new TAG will have been formally issued before this report is completed. As the TAG is pivotal to informing this assessment, it has nevertheless still been considered, despite it still being subject to formal issue.

2.1.3 National and International Standards and Guidance

19 The following international standards and guidance have been used as part of this assessment.

2.1.3.1 IAEA Standards and Guidance

20 The International Atomic Energy Authority (IAEA) has prepared a standard on reactor chemistry (Ref. 5). This is authoritative, wide-reaching and consistent with the assessment and as such is suitable as advisory guidance. Similar guidance is also available for the Spent Fuel Pool, containment systems and for defining limits and conditions of operation (Ref. 5) and these have similarly be used as advisory during the assessment.

2.1.3.2 WENRA

21 A review of reference safety levels defined by the Western European Nuclear Regulators' Association (WENRA) (Ref. 6) found none specific to reactor chemistry. However, reactor chemistry assessment will contribute to meeting the following reference levels:

- Issue E: Design Basis Envelope of Existing Reactors
- Issue H: Operational limits and conditions
- Issue I: Ageing Management
- Issue K: Maintenance, in-service inspection and functional testing

22 The reactor chemistry assessment will also contribute towards the following safety objectives for new power reactors, defined by WENRA (Ref. 6):

- O6: Radiation protection and waste management

2.1.3.3 Chemistry Specific Standards and Guidance

23 A large number of operating pressurised water reactors worldwide base their chemical specifications on standards and guidance produced by industry bodies like the Electric Power Research Institute (EPRI) (Ref. 7) and the German Federation of Large Power Station Operators (VGB Powertech) (Ref. 8). Some of these documents are authoritative and contain detailed justifications for the recommendations made, whilst other simply list limits and action levels. They are also generally based around operational aspects, which tend to mean the focus is on commercial or other concerns rather than safety explicitly. As such they are used as advisory guidance in the course of this assessment.

2.2 Use of Technical Support Contractors

24 No technical support contractors were used to support this assessment.

2.3 Integration with other Assessment Topics

25 While reactor chemistry can be a broad topic, interacting with many other disciplines, there has been no integration necessary in order to complete this assessment.

2.4 Out-of-scope Items

26 The following items are outside the scope of the assessment.

- Information directly copied from the March 2011 GDA PCSR into HPC PCSR2012, unless there is an identified need to revisit the safety claims.

3 LICENSEE'S SAFETY CASE

3.1 HPC PCSR2012 Material Assessed

27 For HPC the PCSR (Ref. 1) refers to the safety report, which is the top-tier/highest level of the safety case at this pre-construction phase. Although described as a report, for HPC it actually consists of a head document, a forward work activities report plus a set of chapters. Each chapter consists of a number of sub-chapters, which in turn are divided into sections.

28 As described above, there is no single chapter, or sub-chapter, of HPC PCSR2012 which contains all of the information relevant to the scope of this assessment.

29 A brief description of the documents and HPC PCSR2012 sub-chapters assessed as part of this assessment is provided below. Note that this is, by design, not a complete description of those sub-chapters but does provide an overview of their content.

30 As defined by the scope of the assessment undertaken here, these only represent those parts of the HPC PCSR2012 which have been updated or are new. This therefore does not represent the totality of the information in the PCSR which could fall within the scope of a typical reactor chemistry assessment. Notably none of the accident analyses chapters (neither chapter 14 – design basis analysis nor chapter 16 – risk reduction and severe accident analyses) have been updated from the March 2011 GDA PCSR, hence are not included below.

3.1.1 Head Document

31 NNB GenCo describes the head document (Ref. 1) as a "*top-level summary of the safety justification*". The head document therefore provides a useful high level route map and introductory commentary on the structure and claims in HPC PCSR2012. In addition, the head document is useful in highlighting the alignment between the information contained in HPC PCSR2012 and the GDA March 2011 PCSR and identifying the main site specific aspects addressed.

32 The head document is arranged into chapters which align with those found in the main safety case. Each chapter in the head document contains a summary of the relevant topic, high-level safety functions for systems chapters, confirmation (or otherwise) of the applicability of the matching GDA sub-chapters, the boundaries/limits of the GDA for that topic, areas for further development, conclusion of why each topic supports the request to enter the construction phase and a list of supporting references.

3.1.2 Forward Work Activities

33 The forward work activities report summarises those areas where NNB GenCo has identified where future work is required to develop the safety case as the HPC design matures. NNB GenCo has identified five main inputs into these, namely GDA Issues, GDA assessment findings, out-of-scope items from GDA, fukushima related activities and other forward work activities. These are presented in turn for each chapter of HPC PCSR2012.

3.1.3 Chapter 5 – Reactor Coolant Systems and Associated Systems

3.1.3.1 Sub-chapter 5.5 – Reactor Chemistry

34 In HPC PCSR2012, March 2011 GDA PCSR Sub-chapter 5.5 "*Reactor Chemistry*" has been split into two new sub-chapters. All of the secondary side chemistry information has been moved into a new sub-chapter, 10.7 (Secondary System Chemistry). Therefore HPC PCSR2012 sub-chapter 5.5 only retains the chemistry information for the primary side water chemistry. NNB GenCo attempt to follow a "*claims-arguments-evidence*" approach in this sub-chapter. Section 1 explains how the chosen parameters support the safety functions of the plant and equipment (i.e. claims and arguments), section 2 provides the supporting analyses (i.e. evidence). Section 3 presents the "*preliminary*" values for the different chemical and radiochemical parameters in the primary circuit.

3.1.4 Chapter 6 – Containment and Safeguard Systems

3.1.4.1 Sub-chapter 6.9 – Containment and Safeguard Systems Chemistry Control

35 HPC PCSR2012 sub-chapter 6.9 is an entirely new sub-chapter. There is no equivalent sub-chapter in the March 2011 GDA PCSR, however the head document (Ref. 1) states that the information contained in this chapter was drawn from sub-chapters 5.5 and 18.2 of the GDA PCSR (although it does not). The purpose of this sub-chapter is to better specify the chemistry and radiochemistry control of the safeguard and containment systems. This chapter therefore discusses a broad range of chemistry related topics including:

- Reactivity control in the safeguard systems (Extra Boration System (RBS [EBS]), Safety Injection System (RIS [SIS]) accumulators and In-containment Reactor Water Storage Tank (IRWST));
- Xenon and iodine mitigation under normal operating conditions through the Safety Injection System operating in Residual Heat Removal Mode (RIS/RRA [SIS/RHRS]) during shutdowns;
- Iodine mitigation under accident situations through sodium hydroxide injection to the Containment Heat Removal System (EVU [CHRS]) and the Annulus Ventilation System (EDE [AVS]) filters;
- Hydrogen management under severe accident situations ensured by the components of the Combustible Gas Control System (ETY [CGCS]);
- Heat removal carried out by Emergency Feedwater System (ASG [EFWS]) and Main Steam Relief Train (VDA [MSRT]) under accident conditions; and
- Radiological monitoring in safeguard systems by the use of the Plant Radiation Monitoring System (KRT [PRMS]) channels.

3.1.5 Chapter 9 – Auxiliary Systems

3.1.5.1 Sub-chapter 9.2 – Water Systems

36 Sub-chapter 9.2, "*Water Systems*", describes various water systems in the HPC plant design. Several of these include updates from the previous version of the HPC PCSR including the Essential Services Water System (SEC [ESWS]), the various demineralised

water systems – the Demineralised Production System (SDA [DPS]), the Nuclear Island Demineralised Water Distribution System (SED [NIDWDS]) and the Conventional Island Demineralised Water Distribution System (SER [CIDWDS]) – the Circulation Water Filtration System (CFI [CWFS]) and the SRU [UCWS].

3.1.5.2 Sub-chapter 9.6 – Auxiliary Systems Chemistry Control

37 A new Sub-chapter 9.6 has been produced for HPC PCSR2012 that covers chemistry control for the systems presented in Chapter 9. Gaps are identified, and Forward Work Activities to address these gaps are summarised. The information presented in this chapter is not included in the March 2011 GDA PCSR. In addition to the specification of the water chemistry of the Chemical and Volume Control System (RCV [CVCS]), Spent Fuel Pond (SFP) and Condensate Storage and Treatment System (TEP [CSTS]), it also discusses the mitigation of process generated hazards such as hydrogen and airborne radioactive contaminants. In addition, the use of the KRT [PRMS] to detect radioactive releases is discussed.

3.1.6 Chapter 10 – Steam and Power Conversion Systems

3.1.6.1 Sub-chapter 10.2 – Turbine Generator Set

38 The turbine set was out of scope of the GDA assessment as this was defined as site specific information, hence was not included in the March 2011 GDA PCSR. This sub-chapter provides information on the turbine generator set for HPC.

3.1.6.2 Sub-chapter 10.4 – Other Features of the Steam and Power Conversion Systems

39 The March 2011 GDA PCSR included the design details for the Main Feedwater System (ARE [MFWS]). Sub-chapter 10.4 of HPC PCSR2012 has been modified to include additional information on systems not included in GDA, including the condenser, condenser extraction system, turbine gland system and some of the feedwater plant systems. It also includes a site-specific update for the Circulating Water System (CRF).

3.1.6.3 Sub-chapter 10.7 – Secondary System Chemistry

40 The new sub-chapter 10.7, "*Secondary System Chemistry",* is based upon information from the March 2011 GDA PCSR sub-chapter 5.5 with only minor wording amendments related to "*sufficient chromium content in secondary side materials*" where flow assisted corrosion may be prevalent. The structure of this sub-chapter is therefore very similar to that presented in sub-chapter 5.5. This sub-chapter provides a description of how the secondary chemistry strategy, along with the choice of secondary circuit materials, allows the minimisation of corrosion, corrosion product transport, accumulation of corrosion products in the steam generators, and the subsequent protection of the integrity of the primary-secondary interface (the second barrier) and hence maintains the nuclear safety role of the steam generators. The chapter also describes how secondary side chemistry is also influenced by environmental impact and plant performance and availability.

3.1.7 Chapter 11 – Discharges and Waste/Spent Fuel

3.1.7.1 Sub-chapter 11.2 – Details of the Radioactive Waste Management Process and Strategy

41 This sub-chapter has been updated for HPC PCSR2012, mainly relating to solid waste and spent fuel strategy, but in addition a discrepancy between sub-chapters 5.5 and 11.2 in the discussion of circuit conditioning has been addressed. Information on chemical effluents is also included in sub-chapter 11.2 for completeness/consistency with the March 2011 GDA PCSR.

3.1.7.2 Sub-chapter 11.4 – Effluent and Waste Treatment Systems Design Architecture

42 Sub-chapter 11.4 gives a description of all systems concerned with the collection and/or treatment and/or discharge of effluent/waste. From a reactor chemistry perspective this includes the Gaseous Waste Processing System (TEG [GWPS]) and Liquid Waste Processing System (9TEU [LWPS]).

3.1.7.3 Sub-chapter 11.5 – Interim Storage Facilities and Disposability

43 Sub-chapter 11.5 is a UK-specific sub-chapter that gives the principles of the solid radioactive waste and spent fuel management strategy for HPC. This provides limited information on the Interim Spent Fuel Store (ISFS) that will be built at HPC.

3.1.8 Chapter 12 – Radiological Protection

3.1.8.1 Sub-chapter 12.2 – Definition of Radioactive Sources in the Primary Circuit

44 Sub-chapter 12.2 has been updated for HPC PCSR2012 to include a definition and justification for the primary circuit radioactive source terms that are the basis of dose rate calculations and radiation exposures, as well as the radiological consequences of accidents described in sub-chapter 14.6. This includes links to the chemistry specific sub-chapters 5.5, 6.9 and 9.6 to include additional information on the origin of the radionuclides that make up the primary circuit source terms, based on the information given in sub-chapters 5.5, 6.9 and 9.6, the main design and operational improvements to minimise the source term are highlighted.

3.1.9 Chapter 18 – Human Factors and Operational Aspects

3.1.9.1 Sub-chapter 18.2 – Normal Operation

45 HPC PCSR2012 sub-chapter 18.2 outlines the methods that will provide operating limits to ensure that design limits are not exceeded for the UK EPR at HPC, including chemistry and radiochemical parameters. Section 6 of this sub-chapter has been updated to address operational chemistry control.

3.1.10 Chapter 19 – Commissioning

3.1.10.1 Sub-chapter 19.1 – Plant Commissioning Programme

46 The March 2011 GDA PCSR sub-chapter 19.1 has been replaced in HPC PCSR2012 with an updated version to include aspects of the HPC specific commissioning programme in place of the generic information contained in the GDA PCSR.

3.2 Progress Since HPC PCSR2012

47 In addition to the material presented in HPC PCSR2012 I have also included other relevant aspects relating to the development of the HPC design and safety case as part of this assessment, including:

- Progress with resolving Assessment Findings from GDA;
- Identification and progress with design changes; and
- Identification and progress with site specific aspects of the HPC design.

48 All of these aspects contribute towards NNB GenCo’s demonstration that it is capable of producing an adequate safety case to support the construction of HPC, and therefore support the purpose of this assessment.

4 ONR ASSESSMENT

49 This assessment has been carried out in accordance with ONR HOW2 BMS policy (Ref. 3).

4.1 Scope of Assessment Undertaken

50 The scope of the assessment is as defined previously in Section 1.2 and 3 of this report.

4.2 Assessment

51 The following sections summarise my detailed assessment of the chemistry elements of HPC PCSR2012.

52 As part of my on-going intervention with NNB GenCo on chemistry related matters for HPC I have previously provided comments on some of these sub-chapters. These were sent to NNB GenCo in March 2013 (Ref. 9), and the detailed comments are repeated in Annex 1 to 5 of this report. These are consistent with the assessment that follows.

53 I have assumed that the next revision of the HPC PCSR will be updated to be consistent with the final consolidated GDA PCSR (November 2012), hence I have not made repeated comments to that effect in the assessment that follows, unless necessary for a specific point.

4.2.1 Alignment of HPC PCSR2012 to the consolidated GDA PCSR

54 Before considering the content of HPC PCSR2012 in more detail, it is worthwhile reviewing the alignment between this and the various GDA PCSR's produced.

55 The integration of reactor chemistry into the UK EPR™ PCSR was poor at the outset of GDA. This meant that the development of the chemistry content of the various PCSR's presented during GDA of UK EPR™ occurred at only a late stage of that project. In fact, the March 2011 GDA PCSR was the first version of the PCSR which included any specific chemistry related elements. This is described further in Section 3 of the Step 4 assessment report for UK EPR™ (Ref. 10). This version of the PCSR (Ref. 11) broadly covers the primary and secondary system chemistries, but does not include auxiliary system chemistry, accident chemistry or related issues such as operational strategies or commissioning. Information on limits and conditions was still under development and therefore represented a work in progress at that stage.

56 The final consolidated GDA PCSR issued in November 2012 was updated to include the resolution of the two reactor chemistry GDA Issues raised at the end of Step 4. The impact of these issues on the safety case is described in the GDA Issue assessment reports (Refs. 12 and 13). For **GI-UKEPR-RC-01** only minor changes were made to sub-chapter 16.1 and 16.2 to reflect the resolution of this GDA Issue (Ref. 14). For **GI-UKEPR-RC-02** in addition to some minor clarifications and amendments, a more significant change was made; see Section 4.17 of Ref. 13. This significant change, addition of a new section essentially reflecting the additional information on the auxiliary systems, was a more profound change to the chapter intended to extend the scope of the systems considered to also include the primary auxiliary systems such as the spent fuel pool and IRWST. It was also necessary to update GDA PCSR sub-chapter 18.2 (limits and conditions) to be consistent with the updates to sub-chapter 5.5. The final versions of

GDA PCSR sub-chapters 5.5 and 18.2 (Refs 15 and 16) were therefore significantly different from those found in the March 2011 GDA PCSR.

57 The general contention made by NNB GenCo, that HPC PCSR2012 is based upon the March 2011 GDA PCSR, is in fact a simplification in the case of reactor chemistry. As can be inferred from the descriptions given in Section 3 of my report and the above, while the structure of HPC PCSR2012 is very different from that developed during GDA the content is more closely aligned with that from the final consolidated GDA PCSR (November 2012). This is shown schematically below, which shows how the March 2011 GDA PCSR was changed for both the consolidated final GDA PCSR and HPC PCSR2012;

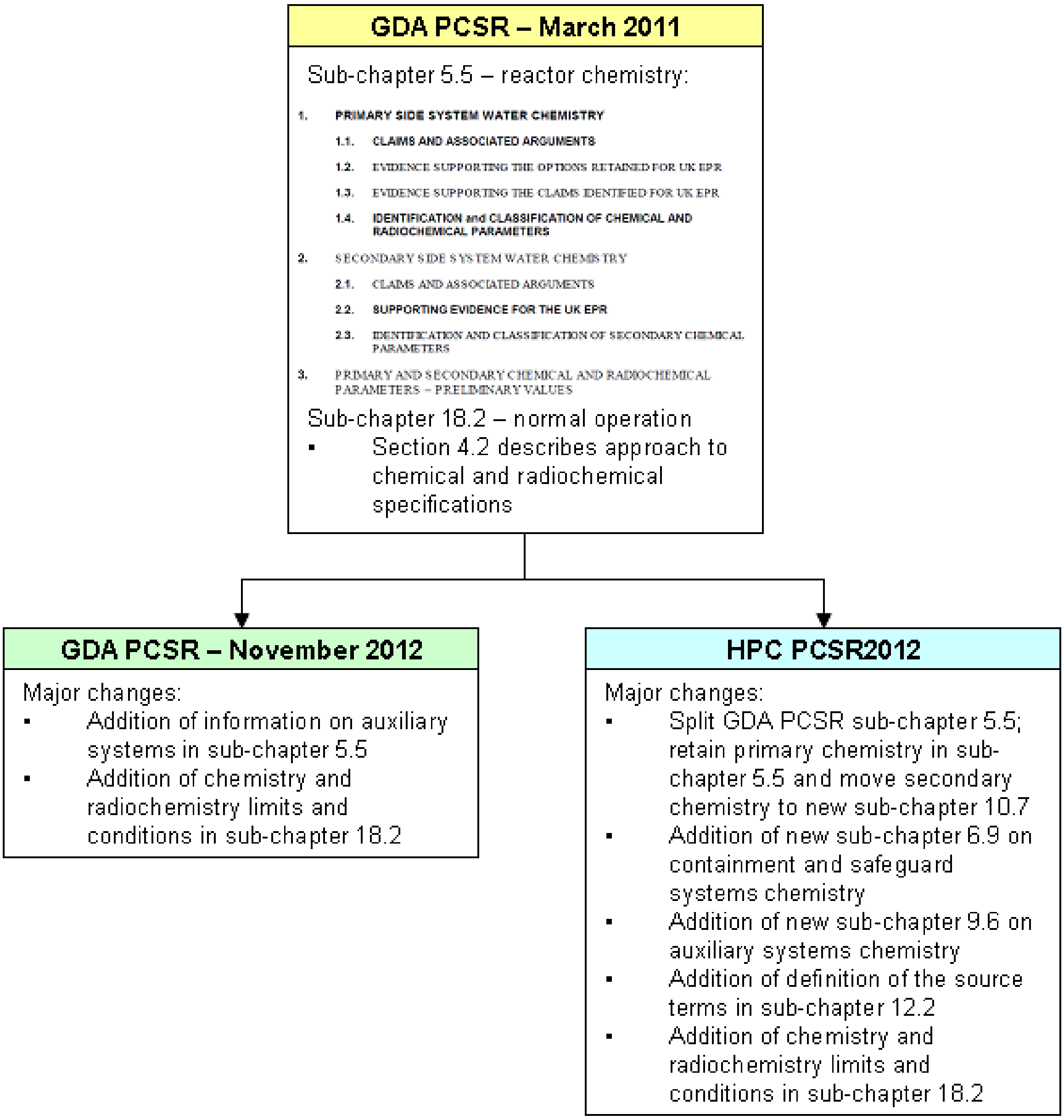

Figure 1 – Development of the March 2011 GDA PCSR for the final consolidated GDA PCSR and HPC PCSR2012

58 In general, I consider that the changes made by NNB GenCo to the structure and overall content of the March 2011 GDA PCSR when preparing the HPC PCSR2012 to be positive. The split into distinct sub-chapters which align with the engineering systems described in the main chapters is, in my opinion, a better way of representing the chemistry related information while keeping it in context of the overall safety case.

59 NNB GenCo have committed to incorporate the changes made for the final consolidated GDA PCSR (November 2012) into the next revision of the HPC PCSR. This may be more convoluted in the chemistry area due to the divergence from the March 2011 GDA PCSR seen above, but is offset to some degree by the fact that some of the consolidated GDA PCSR information is already included. I therefore do not propose to raise an issue on ONR's issues database to cover this.

4.2.2 General Comments on HPC PCSR2012 Reactor Chemistry Related Information

60 In assessing the various sections of the HPC PCSR2012 that are relevant to reactor chemistry it became apparent that there are a number of generic comments that could be made on all of the chemistry related sub-chapters. These are a mixture of technical and presentational matters. For simplicity these are reported here, rather than repeating several times under each sub-chapter. These are (in no particular order):

- The level of quality control is sometimes poor, with many errors that have been missed during checking and/or approval.
- There are problems with the language throughout all 5 documents, but particularly in the "new" sub-chapters of 6.9 and 9.6. While it is often possible to infer what is intended, in a lot of places the safety argument is not clear.
- There is (particularly in sub-chapter 9.6) a lot of unnecessary, often very detailed, non-safety-related or non-chemical-control-related information in the documents, which sometimes masks the key safety arguments. The need or usefulness of this information, particularly at PCSR level, should be reviewed.
- Conversely, none of the sub-chapters contain a simple, concise description of the operating chemistry. For example, sub-chapter 5.5 does not contain a simple description of the primary coolant chemistry control regime (i.e. coordinated boron-lithium with hydrogen and zinc additions). It would be useful to include such a description early in the documents.
- None of the sub-chapters make any specific claims on the chemistry controls reducing risks ALARP. While a lot of the arguments and evidence go towards this, and I judge that such a claim could be made, it is not done. I would expect this to be one of the fundamental claims for a chemistry sub-chapter.
- More consistency is needed between the structures of the different sub-chapters. Sub-chapters 5.5 and 10.7 are much clearer because they only deal with one "system" (i.e. primary or secondary circuit) and have only one chemistry regime each, which is developed via a structured claims-arguments-evidence approach and leads to a set of limits and conditions. Sub-chapters 6.9 and 9.6 both deal with multiple systems in a single chapter, which operate under different chemistry regimes. The chapter attempts to follow the same claims-arguments-evidence structure but does so for all systems considered at once. This makes the content confusing to follow. A better approach may be to structure this on a system by

system basis, with each system having its own claims-arguments-evidence structure. Whatever approach is adopted there is a need to ensure that for chemistry, what is needed, why it's done and how it's controlled, is made clear throughout the submission.

- It was noted that, while the "steady state" chemistry is reasonably well defined, the chemistry controls during transitions between different reactor states is less well documented. As some of these will be safety significant, these should also be documented in the PCSR, particularly any limits and controls necessary.
- It was not clear where any site-specific work has been included or where additional work is in progress to address "open" items in the text (for example development of the strategy for flow accelerated corrosion).
- There is a variable and inconsistent use of French and UK nomenclature and acronyms. This mixed use is confusing and it would be preferable to adopt a single system.
- It would be beneficial to make more use of in-text referencing to highlight the key supporting evidence.
- The engineering/system description sections of each chapter do not refer to the chemistry requirements contained in the chemistry sub-chapter (e.g. the systems in sub-chapter 9.1 to 9.5 make no reference to the chemistry controls needed in sub-chapter 9.6).
- One of the key outputs from the safety case needs to be the limits and conditions necessary in the interests of safety. I would expect more clarity to be provided on these elements of the safety case. It should be made clear what chemistry parameters/specifications will be part of these, even if it is "*preliminary*" at this stage. (Note that this was done as part of the final consolidated GDA PCSR (November 2012) to some degree).

61 I would expect NNB GenCo to consider these points during development of the next revision of the HPC PCSR. Specifically, I judge that there is a need to refine the PCSR such that there is a clear, unambiguous link from the safety case claims, arguments and evidence through to the chemical and radiochemical operating limits, conditions and procedures. I note that existing Assessment Findings for GDA, in particular **AF-UKEPR-RC-01** and **AF-UKEPR-RC-02,** are related to this aspect, however they do not address the wider scope of the PCSR. I have therefore raised the following issue within ONR's issues database (number 2108), to ensure these matters are adequately addressed through routine future regulatory work:

> *The licensee shall review the chemistry elements of the safety case presented in HPC PCSR2012 and ensure that the consistency, visibility and clarity of chemistry related claims, arguments and evidence (or equivalent) is adequate.*

4.2.3 Head Document

62 From a reactor chemistry perspective the head document does not add anything that is not already contained in more detail in the individual sub-chapters. I do judge that the head document is a useful addition to the overall safety case, and welcome the inclusion

of the summary chemistry information, as this clearly demonstrates the importance of chemistry control to safety, particularly to the non-chemist.

63 The single item of note here is that, under section 18.2.2.2, NNB GenCo note that "*Topic Area 9 Reactor Chemistry, Item 1 – All chemistry limits will be defined as part of an operational chemistry strategy*". This simplified statement may not be entirely consistent with ONR expectations in this area, particularly related to licence condition 23 arrangements. However, this broader area is the subject of several GDA Assessment Findings (**AF-UKEPR-RC-01** and **AF-UKEPR-RC-02**) which will provide the appropriate level of ONR oversight of progress in this area.

4.2.4 Forward Work Activities

64 The forward work activities report is NNB GenCo's overview of forward work activities. While this is defined as that "*required to develop the safety case as the HPC design matures*", I am not convinced that the content of this report, at least in the reactor chemistry area adequately reflects this. Most of the activities described seem solely focused on the start of nuclear safety related construction. While I do not consider this to be a significant deficit, I would expect some of the longer and more significant chemistry related activities to feature in this forward work, for example the development of detailed chemical and radiochemical specifications and operating procedures and policies. From my on-going interventions with NNB GenCo, I am confident that such activities are nonetheless, progressing. This is discussed further in Section 4.2.3.

65 Based upon the activities described in the forward work activities report I have identified the following specific items relevant to reactor chemistry:

- Chapter 5 (reactor coolant system and associated systems) –
  - **GI-UKEPR-RC-02** is identified for inclusion in the next revision of the PCSR
  - Under other work, "*a more detailed consideration of corrosion/stress corrosion resistance of construction materials*"
- Chapter 6 (containment and safeguard systems) –
  - **GI-UKEPR-RC-02** is identified for inclusion in the next revision of the PCSR
  - A number of potential resilience enhancements to the HPC design are identified, which could have an impact on reactor chemistry
  - Under other work, "*An investigation of the need to de-oxygenate the ASG [EFWS] storage water in order to limit the possibility of corrosion if the water is used maintaining the circuit at hot shutdown conditions*"
- Chapter 9 (auxiliary systems) –
  - **GI-UKEPR-RC-02** is identified for inclusion in the next revision of the PCSR
  - A number of potential resilience enhancements to the HPC design are identified, which could have an impact on reactor chemistry
  - Under other work, "*A more detailed consideration of corrosion/stress corrosion resistance of construction materials, particularly the pool liner*"
- Chapter 10 (steam and power conversion systems) –
  - **GI-UKEPR-RC-02** is identified for inclusion in the next revision of the PCSR

  - A potential resilience enhancement to the HPC design is identified, which could have an impact on reactor chemistry
  - Under scope of GDA it is noted that "*NNB GenCo are undertaking a systematic review of UK EPR systems to ensure that all systems for which chemistry control is needed in ensuring safety and environmental protection are adequately addressed in the safety case*."
  - Under other work, "*Within GDA PCSR Sub-chapter 10.1 it is stated that "In preparation for the start-up phase, the steam generators are filled with water by the Emergency Feedwater (ASG [EFWS]) system". Because this is a safety-related system and is linked to statements in other sub-chapters of Consolidated GDA PCSR 2011, further detail will be added following completion of the Final GDA PCSR*", "*Further information specifying the pH conditioning agents for secondary systems will be included in HPC PCSR2 Sub-chapter 10.7 once the manufacturer and design is finalised*" and "*The flow assisted corrosion strategy for the UK EPR and the chromium content of certain parts of the secondary system pipework will be developed*".
- Chapter 12 (radiological protection) –
  - Under other work, "*NNB GenCo is undertaking a routine review and validation exercise of the primary circuit source term methodologies and design criteria used in determining the shielding requirements and radiation zoning scheme for the purpose of confirming consistency with accepted UK legislation, best practice and international standards*" and "*Passivation of the primary circuit before initial start-up is mentioned in Sub-chapter 12.1 as a source term reduction measure. A GDA Assessment Finding (although not in the radiation protection topic area) has been raised on the subject of passivation for the UK EPR design and work is ongoing to clarify the means and conditions by which passivation will be achieved*"
- Chapter 16 (risk reduction and severe accident analyses) –
  - **GI-UKEPR-RC-01** is identified for inclusion in the next revision of the PCSR
  - Site specific radiological consequence analysis is noted, under future work
- Chapter 18 (human factors and operational aspects) –
  - Under other work, "*The GDA identifies chemical and radiological parameters that are to be managed, and sets the preliminary limiting values. NNB GenCo will put in place a process that manages the control and monitoring of these parameters and that also manages the case where a control parameter is breached*"
- Chapter 19 (commissioning) –
  - None specifically, although there is a general recognition of further development needed in this area as the safety case develops.

66 I agree that these work activities are entirely reasonable at this stage of the project. I have discussed many of these with NNB GenCo as part of my routine intervention, however I will follow up on those activities which I have not already discussed, to provide assurance that they are being adequately addressed (**Recommendation 1**).

67 I note that there are no reactor chemistry Assessment Findings from GDA that are listed in the forward work plan. They are included in a general sense, by noting that NNB

GenCo have responsibility to resolve these to the timescales indicated by ONR, and by several instances of noting that they exist. However, this does not consider that fact that the ONR reactor chemistry AF milestones were targeted towards the latest possible time that the AF needs to be resolved (generally the milestone before the safety hazard may arise) but the practical timescale needed to resolve these may be considerably sooner. This is a presentational issue with the report. As described in Section 4.2.13 the chemistry team in NNB GenCo have been more proactive in developing a solution to this.

4.2.5 Chapter 5 – Reactor Coolant Systems and Associated Systems

4.2.5.1 Sub-chapter 5.5 – Reactor Chemistry

68 HPC PCSR2012 sub-chapter 5.5 provides a description of the claims, arguments and evidence in relation to the primary circuit chemistry of the UK EPR™ reactors proposed for HPC. The vast majority of information contained in this sub-chapter (estimated to be > 90%) is directly copied from the March 2011 GDA PCSR. The additional information added is generally only the addition of a new introduction section, some minor wording changes to enhance clarity and the addition of section 2.3 and a number of associated tables which identify how the evidence supports the main claims. Importantly, there are therefore no changes to the safety claims assessed as adequate during GDA.

69 As described earlier, the main change from the March 2011 GDA PCSR is the removal of the information on the secondary system chemistry (now part of sub-chapter 10.7). This change has not affected the validity of the remaining information.

70 I previously supplied NNB GenCo with a number of more detailed comments on sub-chapter 5.5. These are given in Annex 1. These generally exemplify the general points given in Section 4.2.2.

71 I am broadly content with the contents of HPC PCSR2012 sub-chapter 5.5 for this stage in the development of the HPC safety case. I do expect further changes to be necessary as the safety case evolves to include resolution of GDA Assessment Findings, design changes, site specific aspects, those areas for improvement identified in Section 4.2.2 are addressed and the development of the operational chemistry programme for HPC matures.

4.2.6 Chapter 6 – Containment and Safeguard Systems

4.2.6.1 Sub-chapter 6.9 – Containment and Safeguard Systems Chemistry Control

72 This sub-chapter is an entirely new subchapter of the HPC PCSR. The head documents states that "*the information of Sub-chapter 6.9 is drawn from Sub-chapters 5.5 and 18.2 of Consolidated GDA PCSR 2011*". This is not correct - this information was not included in the March 2011 GDA PCSR, although some of it appears to be very similar to that contained in the final consolidated GDA PCSR (November 2012). There is however, some entirely new information contained in this sub-chapter.

73 The structure of this sub-chapter is similar to the other chemistry specific sub-chapters of HPC PCSR2012. However, the general claim, arguments and evidence structure is not as well developed. This is related to the generic comment made in section 4.2.2, regarding having multiple systems (with very different chemistry requirements) in the same section.

This is an important aspect of this sub-chapter that needs to be improved, as the key safety claims and arguments are difficult to follow.

74 Sub-chapter 6.9 details the chemistry controls necessary for the containment and safeguard systems described in sub-chapter 6.2 to 6.8 of HPC PCSR2012. These are:

- Containment systems (6.2) – Annulus Ventilation System (EDE [AVS]), containment isolation systems, Combustible Gas Control System (ETY [CGCS]), Leak Rate Control and Testing System (EPP), Core Melt Stabilisation System (CMSS) and the Containment Heat Removal System (EVU [CHRS]).
- Safety Injection System (6.3) – Safety Injection System (RIS [SIS]) and In-containment Reactor Water Storage Tank (IRWST).
- Emergency Feedwater System (6.6) – (ASG [EFWS])
- Extra Boration System (6.7) – (RBS [EBS])
- Main Steam Relief Train (6.8) – (VDA [MSRT])

75 However, I would not expect all of these systems to be included in a chapter purporting to be "chemistry control" as not all of these systems have any controls over the chemistry. Thus I would consider the information on the CHRS, SIS, IRWST, EFWS and EBS to be relevant in this sub-chapter, and these are included. While I welcome the fact that these are included in the section on "*preliminary specifications*" I note that the general approach seems to be to define the chemistry in all of the systems individually. I would expect this to be considered further where, for example, one system simply takes the output from another (i.e. the CHRS uses the IRWST water) or where there isn't actually any chemistry control performed (i.e. will the water in the CHRS actually be "controlled" in this sense?).

76 The sub-chapter also includes information on the AVS, CGCS and MSRT, plus the Plant Radiation Monitoring System (PRMS) (not part of chapter 6 systems), all of which do not have any chemistry control requirements. The information presented for each of these falls within the second or third bullet point of the definition of reactor chemistry given in para. 4, when this sub-chapter is more aimed at the first bullet point. I would therefore expect some of this information to appear elsewhere in the PCSR, if necessary.

77 Also of note in this sub-chapter:

- Section 3.2.1 described the mitigation of iodine releases during accident conditions. I have not assessed this in detail as **AF-UKEPR-RC-50** refers.
- Section 3.4.1 described the introduction of oxygenated feedwater into the Steam Generators (SGs) when the EFWS is used. I have not assessed this in detail as **AF-UKEPR-RC-28** refers. This is also identified under chapter 6 and 10 of the forward work activities report.
- Section 4 and 5 describes the arguments and evidence associated with the radiochemical elements of the containment and safeguard systems. I note that section 4 states that "*The radiochemistry described below corresponds to the control parameters associated with the safety control. The others are developed in chapter 9.6*". I remain unconvinced why this approach has been taken, as this only confuses the safety case further. Section 5, "*radiochemical evidence associated with safety controls*", attempts to define the radiochemical control necessary. These mostly relate to the residual heat removal system during shutdowns (RIS/RRA [SIS/RHRS]). I have two concerns with this approach:

- While this does relate to the RHRS, it is part of the much wider holistic considerations that need to be considered during shutdowns (and start-up) of the plant. By separating to this extent it potentially "dilutes" the safety case requirements that must be met during these transient, but very important periods of operation. This is related to the general comment made in Section 4.2.2.
- The information presented is extremely detailed, so much so that I would question it's inclusion at the PCSR level. I have not assessed the numerical values proposed in this section as they are defined as "*preliminary*" in the PCSR. I do however, consider that the approach taken appears appropriate.

The issue described in Section 4.2.2 of this assessment, related to adequacy of the safety case, also applies here.

78 I previously supplied NNB GenCo with a number of more detailed comments on sub-chapter 6.9. These are given in Annex 2. These generally exemplify the general points given in Section 4.2.2, plus those described above.

79 Overall, I consider that further work is required to allow sub-chapter 6.9 to meet my expectations for a PCSR, as outlined above. I do not judge that the deficiencies identified raise or hide any fundamental nuclear safety concerns, although I find that they complicate the arguments made and make the structure and key safety claims more opaque. I would therefore expect resolution of them to be progressed as part of the next revision of the HPC PCSR.

4.2.7 Chapter 9 – Auxiliary Systems

4.2.7.1 Sub-chapter 9.2 – Water Systems

80 As described previously, sub-chapter 9.2 of HPC PCSR2012 contains updates to a number of water systems for HPC. These include:

- Essential service water system (SEC [ESWS]) – the updates are generally minor from a reactor chemistry perspective, clarifying or updating the system design or functions.
- Demineralised water systems – most of the updates relate to additional site specific details relating to the demineralised water system designs for HPC. These are generally minor or points of clarification. I note however that this now states that "*The SDA (demineralised production system), SED and SER systems play no part in the safety case*". I strongly disagree with this statement, as these systems produce and distribute water of the correct chemical quality to a number of safety systems in the UK EPR™ design (for example, the SED supplies the primary circuit with make-up water). Unrevealed failure of these systems could have an impact on nuclear safety. I have therefore raised the following issue within ONR's issues database (number 2109), to ensure these matters are adequately addressed through routine future regulatory work:

  The licensee shall review if safety claims are necessary for the demineralised water treatment and distributions systems (SDA, SED and SER) for HPC.

- Circulation Water Filtration System (CFI [CWFS]) – more site specific information is added to the CWFS design for HPC. None of the additions are chemistry related.
- Ultimate Cooling Water System (SRU [UCWS]) - more site specific information is added to the UCWS design for HPC. None of the additions are chemistry related.

4.2.7.2 Sub-chapter 9.6 – Auxiliary Systems Chemistry Control

81 Sub-chapter 9.6 is the most voluminous of all the chemistry sub-chapters in HPC PCSR2012. It is also composed entirely of new material compared to the March 2011 GDA PCSR. The general comments given in Section 4.2.2 of my report are most prominent and numerous throughout this sub-chapter. An additional point applicable to this sub-chapter is that the precision of the text varies significantly; sometimes it is very precise (down to equations and numeric values) whereas in other areas it is left almost to interpretation. Some of this may represent the current progress, but it is not helpful in understanding the balance of risks presented in the safety case.

82 A large part of the information in sub-chapter 9.6 appears to have originated from the documents produced to respond to **GI-UKEPR-RC-02**. These were assessed in Ref. 13. While they were judged to be adequate to resolve the GDA Issue, I had a number of reservations about these reports, which are more important now that they appear to form the basis for this PCSR sub-chapter. In particular it is notable that I required EDF and AREVA to produce an additional "*roadmap*" document as the evidence trail in the original responses was difficult to follow. Unfortunately the same seems to be true of this sub-chapter, as exemplified by the comments that follow.

83 As with sub-chapter 6.9, clearly the scope in producing this sub-chapter was to describe all of the applicable systems in sub-chapters 9.1 to 9.5. The complication with this approach is that "auxiliary systems" covers a broad range of systems with very different chemistry, functional and safety requirements. The relevant systems include:

- Fuel handling and storage (9.1) – Spent Fuel Cooling and Purification System (PTR [FPPS/FPCS])
- Water Systems (9.2) – Essential Services Water System (SEC [ESWS]), the various demineralised water systems – the Demineralised Production System (SDA [DPS]), the Nuclear Island Demineralised Water Distribution System (SED [NIDWDS]) and the Conventional Island Demineralised Water Distribution System (SER [CIDWDS]) – the Circulation Water Filtration System (CFI [CWFS]) and the SRU [UCWS]
- Primary System Auxiliaries (9.3) – Nuclear Island Sampling System (REN [NSS], RES and TEN), Chemical and Volume Control System (RCV [CVCS]), Coolant Purification, Degasification, Storage and Treatment System (TEP [CSTS]) and Reactor Boron and Water Make-up System (REA [RBWMS]).
- Heating, Ventilation and Air-conditioning Systems (9.4) – numerous ventilation systems including the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), Fuel Building Ventilation System (DWK [FBVS]) and Continuous Containment Ventilation System (EVR [CCVS]). This includes the water filled cooling systems such as the Safety Chilled Water System (DEL) and the Operational Chilled Water System (DER).

- Other supporting system (9.5) – this includes the fire protection, diesel generator, compressed air and gas distribution and storage systems.

84 As in sub-chapter 6.9, I do not believe that some of the systems considered are relevant as, while they might have some chemistry related function (i.e. the HVAC systems rely on chemical filters), there is no on-going "chemical control" (i.e. no chemicals are added to the fluid in the system). I think it is important that the scope of the chemistry sub-chapters is clear, and it may be that some of this information should reside elsewhere in the PCSR, if necessary.

85 The sub-chapter approaches this large variation in systems covered by splitting into sections which align with the various PCSR sub-chapters. The initial section however attempts to tie each of these systems back to the main safety claims applied in sub-chapter 5.5 for the primary chemistry. This is more successful for the primary auxiliary systems, but less so for others (such as the ventilation systems). Importantly, and unlike either sub-chapter 5.5 or 10.7, the purpose and basis of chemistry control in these systems is not initially summarised (and in some instances is difficult to find anywhere). Even where this is most successful, I have identified instances where the generalisations used are not consistent with the requirement for specific systems (for example, not all primary auxiliary systems dose hydrogen, but the text implies that this is the case). This makes following the subsequent arguments difficult. Importantly, it is not clear how the chemistry applied supports the functional requirements identified for the different systems. This is an important part of the issue raised in Section 4.2.2, as the adequacy of the safety case is also informed by its usability.

86 The arguments made essential consist of "*adequate materials*" and "a*dequate operating chemistry*" being applied to the respective system. I find this to be overly simplistic. This has further effects in the presentation of the safety case in that a given species may be an additive or impurity depending on the particular system. For example, under the primary auxiliary systems, sodium is noted as below 0.1 mg kg^{-1} in the CVCS (impurity) but at 35% in the CHRS (additive) (and the CHRS is not covered in chapter 9, but 6). I judge that comparing these in this manner in inappropriate and potentially misleading. This also potentially masks the more significant hazards, and how they are mitigated.

87 Some more specific points include:

- Section 3 ("*Chemistry and radiochemistry of primary auxiliary, fuel handling and storage systems*") is the most significant section of sub-chapter 9.6. It deals with the main primary auxiliary systems, such as the CVCS, FPPS/FPCS and RBWMS. While there are some similarities between the chemistry requirements for these systems, the safety claims, arguments and evidence associated with these are complicated to follow as presented.
- Section 5 ("*chemistry and radiochemistry of HVAC systems*") discusses mainly HVAC abatement performance. It does not provide any information on the chemistry controls necessary in the water systems which support the HVAC. Table 7, however suggest that the DER and DEL systems require phosphate conditioning.
- Section 6.1 ("*the role of chemistry/radiochemistry in fire protection systems*") provides some information on the JAC fire protection system which suggests that the chemistry of the JAC system may need more consideration as the safety case develops. This suggests that chemistry control is applied but it is not monitored or controlled. Also, the periodic test of using the JAC to fill the EFWS tanks only appears to be under administrative control to stop inadvertent filling. This may need

further thought to ensure that the EFWS tanks do not become contaminated and hence potentially the SGs.

- Section 6.2 ("*the role of chemistry/radiochemistry in diesel generator units*") appears very preliminary. Further consideration to these aspects will be necessary as the safety case develops, particularly specifications for diesel fuels and chemical control of any cooling circuits.
- Section 6.4.1 ("*SGN: nitrogen gas distribution system*") mentions the Gaseous Waste Processing System (TEG [GWPS]), in terms of the nitrogen supply requirements. I note that the chemistry/radiochemistry control in the TEG are not covered here, nor elsewhere in HPC PCSR2012. **AF-UKEPR-RC-37** refers.
- Appendix A ("*chemical-radiochemical monitoring*") compiles the chemistry and the radiochemistry parameters of each of the auxiliary systems that should be monitored. It is notable that:
  - This list includes system not covered under chapter 9 (e.g. RCS, TEG, EVU etc.)
  - No other chemistry sub-chapter contains similar information.
- "*Preliminary specifications*" are identified for CVCS (downstream of demineralisers), RBWMS, TEP (distillates), FPPS/FPCS (fuel pond), CCWS, SED and SER. In addition a specification is provided for the Liquid Waste Processing System (TEU [LWPS]), which is not covered under sub-chapter 9.6. I am not convinced that these are all that are necessary and note that none are provided for DPS, DEL, DER, JAC or diesel generators.

88 An important point is that this sub-chapter (nor other chemistry sub-chapters) does not report about boric acid recycling and degasification to the extent I would expect. While some of this will come down to operator choices, I judge that there needs to be enough in the PCSR to make it clear what the hazards and controls are and if there are any limits or conditions that result. I do not think that sub-chapter 9.6 is adequate in this regard. The existing GDA Assessment Fining, **AF-UKEPR-RC-04**, is adequate to ensure this matter is progressed, but I would expect the next revision of the HPC PCSR to show some progress on these important aspects.

89 I previously supplied NNB GenCo with a number of more detailed comments on sub-chapter 9.6. These are given in Annex 3. These generally exemplify the general points given in Section 4.2.2, plus those described above.

90 Overall, I judge that sub-chapter 9.6 is inadequate, as currently presented. It is not clear what this sub-chapter is trying to convey or achieve. The approach is very confusing and I do not consider that the safety claims are adequately defined and substantiated. However, based on the underlying technical content and my existing knowledge of these systems I do judge that NNB GenCo could make an adequate safety case in this area, but significant improvements will be needed at the next revision of the HPC PCSR to address this. The issue raised on adequacy of the safety case under Section 4.2.2 of this report is very significant for this sub-chapter.

4.2.8 Chapter 10 – Steam and Power Conversion Systems

4.2.8.1 Sub-chapter 10.2 – Turbine Generator Set

91 Sub-chapter 10.2 contains information on the turbine generator for HPC. The information is very limited, noting that further details will be added as the design and safety case develops. I am content that this is reasonable for this stage of development of the PCSR.

92 I note that, as is common, the system will include hydrogen rotor and stator cooling and demineralised water inside the stator windings. I will review the safety significance of these systems as the design matures and more information becomes available, although I only expect these to be minor.

4.2.8.2 Sub-chapter 10.4 – Other Features of the Steam and Power Conversion Systems

93 Many of the secondary circuit systems of UK EPR™ were outside of the scope for GDA. Sub-chapter 10.4 of HPC PCSR2012 has been updated to include some information on these. Notable additions include details on the Condenser and the Condensate Extraction Systems (CEX), the Turbine By-Pass System(GCT [MSB]), the Feedwater Plant Systems (Low Pressure Feedwater and Heater System(ABP), Feedwater Tank and Gas Stripper System (ADG), Motor-driven Feedwater Pump System (APA [MFWPS]), High and Medium Pressure Feedwater Plant and Heater System (AHP), Start-up and shutdown feedwater system (AAD [SSS])), the Cooling Water System (CRF) and the Turbine Gland Steam System (CET).

94 Most of the systems are described as "*non safety classified*" in HPC PCSR2012. This neglects the importance of some parts of these system to maintaining an adequate quality feedwater supply to the steam generators assuring their integrity, hence they are indirectly associated with the safety function of "*containment of radioactive substances*".

95 Information on the Steam Generator Blowdown System (APG [SGBS]) is identical to the March 2011 GDA PCSR.

4.2.8.3 Sub-chapter 10.7 – Secondary System Chemistry

96 Sub-chapter 10.7 contains those sections of the March 2011 GDA PCSR related to secondary circuit chemistry which have been removed from sub-chapter 5.5. This includes section 2 ("*secondary side system water chemistry*") and part of section 3 ("*secondary side chemical and radiochemical parameters*"). No technical information has been altered during the transfer of text. However, minor changes from GDA have been made to improve clarity of the document. As with sub-chapter 5.5, there are no changes to the claims assessed as adequate during GDA.

97 I previously supplied NNB GenCo with a number of more detailed comments on sub-chapter 10.7. These are given in Annex 4. These are relatively minor.

98 As many elements of secondary chemistry were still being developed during GDA for UK EPR™, I raised a number of Assessment Findings (**AF-UKEPR-RC-27** to **AF-UKEPR-RC-36**). In particular **AF-UKEPR-RC-27** and **AF-UKEPR-RC-33** require detailed justifications for aspects of the secondary circuit chemistry and design. I would expect resolution of these to have an impact on this sub-chapter. Progress with AF resolution is described in section 4.2.13 of my report.

99 I am broadly content with the contents of HPC PCSR2012 sub-chapter 10.7 for this stage in the development of the HPC safety case. I do expect further changes to be necessary as the safety case evolves to include resolution of GDA Assessment Findings, design changes, site specific aspects, those areas for improvement identified in Section 4.2.2 are addressed and the development of the operational chemistry programme for HPC matures.

4.2.9 Chapter 11 – Discharges and Waste/Spent Fuel

4.2.9.1 Sub-chapter 11.2 – Details of the Radioactive Waste Management Process and Strategy

100 From a reactor chemistry perspective, this sub-chapter has been updated to better reflect the content of the March 2011 GDA PCSR. In general, the changes mainly represent summaries of more detailed chemistry information contained in sub-chapter 5.5, or elsewhere. The changes represent improvements to descriptions and links to the chemistry aspects of the GDA PCSR, but have not changed the claims previously assessed during GDA. Some minor comments are:

- The references to sub-chapter 5.5 in the text are incorrect. These may refer to the March 2011 GDA PCSR, but not HPC PCSR2012.
- There does not appear to be any link to sub-chapter 12.2, which contains the source terms used for the plant. This means that some of the information in the text may be factually incorrect, for example under section 1.1.1, those isotopes claimed as "*mainly formed*" are not; they are those with the longest half-lives that are therefore the most important for discharges.

101 Overall, I consider that HPC PCSR2012 sub-chapter 11.2 is adequate from a reactor chemistry perspective at this stage of development of the safety case.

4.2.9.2 Sub-chapter 11.4 – Effluent and Waste Treatment Systems Design Architecture

102 The March 2011 GDA PCSR sub-chapter 11.4 has been updated in HPC PCSR2012 to include all the site-specific system differences for HPC in accordance with the fullest design description available at that time. The information on the gaseous and liquid radwaste systems however, is the same as that from GDA.

103 I note that there is no "chemistry control" sub-chapter for chapter 11 of HPC PCSR2012. This appears to have been an omission, as there are certainly some chemistry control aspects to these systems. **AF-UKEPR-RC-37** refers.

4.2.9.3 Sub-chapter 11.5 – Interim Storage Facilities and Disposability

104 Sub-chapter 11.5 is a new site specific sub-chapter for HPC PCSR2012. From a chemistry perspective the main addition is section 2 relating to the new Interim Spent Fuel Store (ISFS). The March 2011 GDA PCSR specified either wet or dry storage of spent fuel from HPC as being adequately safe options. NNB GenCo has subsequently decided upon a wet storage facility, to be constructed on the HPC site. The level of design for this facility is currently only at the conceptual stage, hence specific details are lacking. However, the basic design is for a large volume pool of demineralised non-borated water,

containing the fuel assembly storage racks, the immersed heat exchangers, the pool water filtration, purification and the skimming systems. The heat exchangers will use a secondary closed loop water cooling system.

105 I am content that this is an adequate position for this stage in the development of the safety case for HPC. I will assess the chemistry requirements for the ISFS and its associated systems as the design develops.

4.2.10 Chapter 12 – Radiological Protection

4.2.10.1 Sub-chapter 12.2 – Definition of Radioactive Sources in the Primary Circuit

106 HPC PCSR sub-chapter 12.2 consolidates information presented in the March 2011 GDA PCSR (sub-chapters 11.1 and 12.2) into a single sub-chapter which defines and justifies the source terms for UK EPR™. While much of the text is new, the information presented has not changed from that presented in GDA. The text changes actually represent an improvement on the GDA PCSR as they more strongly link the derived source terms with the underlying chemistry, particularly that in sub-chapter 5.5. Some of the new text appears to originate from the reports produced in response to GDA Issue **GI-UKEPR-RC-02**.

107 I note that resolution of **AF-UKEPR-RC-69** may have an important impact on the information presented here, although I still consider that the source terms presented are reasonable for use at this stage.

4.2.11 Chapter 18 – Human Factors and Operational Aspects

4.2.11.1 Sub-chapter 18.2 – Normal Operation

108 In general this chapter has changed little since that produced for the March 2011 GDA PCSR. As noted in the text there will be a continuous development of this sub-chapter as the safety case is developed. This chapter describes the approach to the development of Operating Technical Specifications (OTS) for HPC.

109 The main difference from GDA is that the chemical and radiochemical specifications are now within a separate section (6) of the document. The text in this section has therefore been re-written extensively. It is however, very closely linked to the intent described in the GDA PCSR. While the GDA PCSR was deemed adequate to support a DAC decision for UK EPR™, in the reactor chemistry area it was more a statement of intent and I recognised that individual licensees may choose alternative approaches. However, having assessed the HPC PCSR2012 sub-chapter I note that:

- The sub-chapter is not clear on what constitutes the OTS, "*Chemical and Radiological Specifications*" and "*Operational Chemistry Control*". There appears to be some confusion over terminology throughout the sub-chapter.
- "*The boron concentration requirements in the RCP [RCS] and the primary auxiliary system (Fuel Pool, IRWST, EBS, RIS Accumulators) are for reactivity control and are linked to, but do not arise from, a chemistry requirement.*", while this may be the case, these very important requirements do not appear to be noted elsewhere in this sub-chapter and hence I remain uncertain where they will be covered.

- The text states that "*Depending on the approach adopted in developing the OTS, the radiation and chemistry limits may either appear in the OTS and chemical and radiochemical specification documents (different from the NUREG approach), or only in chemical and radiochemical specification documents. The approach applied to the UK-EPR will be decided at a later stage*". This implies that there could be no chemical or radiochemical limits in the OTS. This would be a significant deficit in meeting my expectations and does not appear consistent with ONR guidance on limits and conditions (NS-TAST-GD-035, Ref. 4). As such I consider it unlikely that a safety case on this basis would be acceptable.
- Section 6.2 notes several parameters that "*need to be monitored during normal operation to comply with the safety objectives of the plant*". I would infer these to be the OTS parameters. If this is the case I would consider this list to be significantly inadequate. My expectation would be for many more chemistry and radiochemistry parameters to be at the OTS level.
- The chapter appears to consider primary, secondary and auxiliary systems (CHRS and CCWS) only. This sub-chapter does not appear to have kept pace with the development of the other chemistry sub-chapters within HPC PCSR2012.
- The subsequent sections generally summarise the more detailed chemistry sub-chapters. There is no attempt to link the "*preliminary specifications*" from these to the OTS limits.

110 One of the main decisions to be made is which chemical parameters are parts of the OTS and which are not. One of the main purposes of this chapter should be to justify this decision and why it reduces risks ALARP. **AF-UKEPR-RC-02** refers. I would expect further revisions of the HPC PCSR to provide additional information on this aspect, which will be very important to the adequacy of the chemistry aspects of the safety case moving forward towards operations.

111 I previously supplied NNB GenCo with a number of more detailed comments on sub-chapter 18.2. These are given in Annex 5. These are relatively minor.

4.2.12 Chapter 19 – Commissioning

4.2.12.1 Sub-chapter 19.1 – Plant Commissioning Programme

112 Sub-chapter 19.1 develops the generic commissioning plan presented for GDA with HPC specific details. From a chemistry perspective the main point to note is the specific inclusion of "*Passivation and chemical conditioning of the RCP [RCS]*" during the hot functional testing phase. I am content that this sub-chapter is adequate for the present stage, from a chemistry perspective. I note that **AF-UKEPR-RC-03**, **AF-UKEPR-RC-20** and **AF-UKEPR-RC-21** are all relevant to this sub-chapter.

4.2.13 Progress Since HPC PCSR2012

113 HPC PCSR2012 was issued in December 2012. NNB GenCo has continued working to develop the design and safety case in the interim. It is therefore relevant to consider progress made in this time as part of the present assessment. I have summarised this below under the following main work areas. This information has mainly come from my routine interventions with NNB GenCo (Refs. 17, 18 and 19).

114 My general expectation would be that the next revision of the HPC PCSR takes account of development in each of these area, so far as is reasonably practicable.

4.2.13.1 GDA Assessment Findings

115 There were 55 Assessment Findings (AFs) raised in the reactor chemistry topic at the end of GDA Step 4 for UK EPR™. An additional 14 were raised during resolution of the two reactor chemistry specific GDA Issues, increasing the total to 69.

116 NNB GenCo has been working on developing resolution plans for these AFs. To aid with this a prioritisation scheme has been developed, with those considered most likely to impact design, contracts or procurement or present resolution challenges prioritised highest. I consider this a proactive and positive approach by the NNB GenCo chemistry team.

117 NNB GenCo have also reviewed the AFs and allocated them to the topic area which has the expertise most suited to resolve them. This has meant that some reactor chemistry AFs have been allocated to other topics for resolution, such as severe accidents, fuel and core, nuclear steam supply system or radiological consequences. Similarly some AFs from other ONR topic areas have been taken on by the reactor chemistry team in NNB GenCo. In all cases the chemistry team in NNB GenCo retain an input to all "RC" AFs. I have no concerns over this approach, as this ensures that the most appropriate resolution should be provided. I have stated to NNB GenCo that, irrespective of who takes the lead in NNB GenCo, the scope of my responsibility extends to all reactor chemistry AFs. Similarly I will not assess any AFs from other topic areas, unless they have an impact on reactor chemistry.

118 The prioritisation and allocation of AFs is under continual review in NNB GenCo, and has evolved during the period. As of October 2013 NNB GenCo had identified 36 reactor chemistry AFs for resolution by the chemistry team, with 14 AFs of these in the highest priority category.

119 I have not yet received any resolution plans for any AFs. As reactor chemistry is mainly related to operations, many of the ONR milestones for these are late in the project hence this is not surprising, and I remain content that adequate progress is being made. I have discussed several proposed resolution strategies with NNB GenCo for the following:

- **AF-UKEPR-RC-16** - pressuriser vapour phase sampling
- **AF-UKEPR-RC-18** - post accident sampling
- **AF-UKEPR-RC-22** - accidental over-cooling of the spent fuel pool
- **AF-UKEPR-RC-30** - nitrogenous discharges
- **AF-UKEPR-RC-32** - automatic protection against feedwater impurity ingress
- **AF-UKEPR-RC-52** - activation of the sacrificial concrete

120 I provided feedback to NNB GenCo on their intended strategies, highlighting areas of higher significance to ONR or where I judge further justification may be required. I have noted several instances where I believe that the safety justification may be difficult, but I have not identified any fundamental obstacles to resolution. Based on this sample I am content that NNB GenCo are approaching resolution of the reactor chemistry assessment findings in an appropriate manner and appear to understand both the intent and type of evidence needed for resolution.

121 I have agreed to review all resolution plans for reactor chemistry assessment findings produced by NNB GenCo. This will inform my sampling strategy for subsequent resolution documents.

4.2.13.2 Design Changes

122 I have discussed the following areas with NNB GenCo, which are where the design or safety case for HPC has changed since the completion of GDA:

- Secondary chemistry conditioning – The secondary chemistry for HPC will be defined post GDA. This will be one of the potential options upon which the GDA for UK EPR™ was based. **AF-UKEPR-RC-01**, **AF-UKEPR-RC-02** and **AF-UKEPR-RC-27** to **AF-UKEPR-RC-36** are all relevant.
- Hydrazine storage - In the UK context, it is normal practice to reduce the concentration and increase the volume of stored hazardous chemicals. This takes account of COMAH regulation requirements. This is the opposite of French practice. The Chemical Conditioning (Injection with Reagent) system (SIR) for HPC was therefore redesigned to take this into account and HPC will use a larger volume of 5% N_2H_4.
- Hydrogen packs and storage - NNB plan to follow the Sizewell B practice of Hydrogen delivery and storage (larger volumes of bottles stored horizontally on trailers) rather than the Flamanville approach to have crates of 18 vertically positioned bottles, which greatly reduces operator manual handling actions. The design of the Hydrogen storage area is currently being assessed to allow for this preferred method of delivery and storage.
- Degasser design - An additional site degasser (0REA), in the demineralisation plant, has been included in the HPC design in order to degas demineralised water for the TEP system and primary circuit make-up water, leaving the TEP6 (CSTS) degasser to degas primary circuit coolant let-down in order to remove radioactivity before it is sent to waste. NNB GenCo is currently working on the detailed design of the degasser.
- Intermediate Spent Fuel Store (ISFS) - There are chemical implications, which will be studied within the framework of the resolution of **AF-UKEPR-RC-26**, associated with the movements of the fuel from wet conditions in the SFP to dry conditions during removal and back to wet conditions in the ISFS. The chemical control requirements and arrangements for the ISFS pond itself would need to be considered at a later point in the design of the facility.
- Laboratory strategy and facilities - The decision was taken to remove the analysis of radioactive samples from the lab in the OSC building, in order to avoid having a satellite RCA with the implicated operational and maintenance concerns. The intent is to make use of a dedicated room in the hot lab in the NAB, to perform low-level activity analysis in this facility.

123 I remain content NNB GenCo is approaching design changes in an adequate manner.

4.2.13.3 Site Specific Aspects of the HPC Design

124 I have discussed the following areas with NNB GenCo, which are where the design or safety case has been adapted to meet the HPC site requirements:

- Operational environmental permits – The NNB chemistry team works closely with the environment team on operational environmental permits, particularly the RSR Permit and associated commitments. This has impacts on the chemistry strategy which will/could be employed at HPC.
- COMAH application –NNB propose that the COMAH application will need to be submitted 12 months prior to the arrival on site of the first chemicals which would require HPC to be classified as a COMAH site. This has already impacted on the design as described in Section 4.2.13.2, above.
- Seawater chlorination strategy – The original HPC design included a seawater chlorination system to control biofouling risks. Neither HPA nor HPB have ever had or needed protection from biofouling. The decision was therefore taken to remove the chlorination (CTE) system from the HPC design. However, injection points have been maintained and there is provision for a space on site should a CTE be needed in the future. This was discussed with NNB GenCo during HPC site licensing.
- Chemical internal hazards - Release of hazardous chemicals or noxious substances from on-site sources is a new internal hazard which was not included in GDA. Work to assess this hazard will be led by the NNB Internal Hazard topic lead and may require technical support from chemistry in the future, particularly for review of the methodology which will be proposed.
- Atmospheric corrosivity – This is under assessment for the HPC site, along with the appropriate controls for delivery and storage of components, to ensure cleanliness and protection from corrosion.
- Radwaste facilities - on the two unit HPC site, there will be a shared Effluent Treatment Building (ETB) at unit 1. This was not formally considered during GDA, but I noted that GDA was based upon a radwaste facility design that had the capacity for two EPR units.

125 I remain content NNB GenCo is adapting the generic UK EPR™ design to accommodate the specifics of the HPC site in an adequate manner.

4.2.13.4 Other Matters

126 It is worth mentioning one further area of on-going work by NNB GenCo that is relevant to the present assessment – the “*chemistry manual*”. NNB propose to produce a chemistry manual for HPC. The exact scope of this document is yet to be fully defined but will be a compendium of specifications and requirements for the chemistry systems at HPC. This will therefore either be a key reference to the safety case or parts of the specifications could also be copied into the safety case. Work is on-going to define this document further. In either case this could significantly impact on the next revision of the HPC PCSR, depending upon progress.

127 The Chemical/Radiochemical specifications for FA3 will be send to the French Regulator at the same time that the DMES (Dossier de Mise en Service) in October 2014. The Chemical/Radiochemical Specification of FA3 will then be used as the basis to produce the Chemical Program for HPC.

128 **AF-UKEPR-RC-01**, **AF-UKEPR-RC-02** and **AF-UKEPR-RC-03** are all relevant here.

4.3 Comparison with Standards, Guidance and Relevant Good Practice

129 In assessing the reactor chemistry aspects of HPC PCSR2012 I have considered relevant SAPs (Table 2), TAGs (Table 3) and relevant good practice. Any shortfalls identified against this guidance are discussed at the relevant point within this report.

5 CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

130 This report presents the findings of the ONR assessment of the reactor chemistry aspects of the extant HPC safety case (known as HPC PCSR2012) in order to form a judgement on the adequacy of progress towards meeting ONR's requirement for an adequate Pre-Construction Safety Report (PCSR) for Hinkley Point C (HPC).

131 There is no single chapter, or sub-chapter, of the HPC PCSR2012 that contains all of the information relevant to this assessment. Most of the information assessed was contained within sub-chapters 5.5, 6.9, 9.6 and 10.7 which cover reactor, safeguard and containment, auxiliary and secondary circuit system chemistry respectively. Additional chapters also contain other relevant information which formed part of this assessment including on source terms and operating limits and conditions. A total of 12 new sub-chapters were assessed, plus the head document and forward work activities report.

132 HPC PCSR2012 is a mixture of new information and information derived from the GDA process. In some instances the GDA information was taken directly from the March 2011 GDA PCSR, in other cases it was distilled from the final consolidated GDA PCSR from November 2012 or reports produced to resolve GDA Issues for UK EPR™. This assessment has therefore focused on those parts of HPC PCSR2012 that have changed from the March 2011 GDA PCSR, as this represents a baseline level of information that ONR have previously assessed.

133 At a high level I recognise the proactive approach taken by NNB GenCo in developing the chemistry aspects of the HPC PCSR. This is significantly different from that taken during GDA, involving a more systematic review and definition of the chemistry requirements for the various plant systems and I judge this to be a positive improvement which will help in developing the safety case going forward.

134 However, my assessment has highlighted that there is a level of inconsistency between the various chemistry sub-chapters, both in terms of quality and approach. Those which are based closely on the March 2011 GDA PCSR (namely sub-chapters 5.5. and 10.7) are much better than those which are new for HPC PCSR2012 (sub-chapters 6.9 and 9.6), although all sub-chapters are in need of improvement to some degree. The key points which have arisen from my assessment are therefore:

- In terms of quality, I have identified many errors that have been missed during checking and/or approval and there are problems with the language throughout all 5 sub-chapters, but particularly in the “new” sub-chapters of 6.9 and 9.6. While it is often possible to infer what is intended, in a lot of places the safety argument is not clear.
- In terms of approach, there does not appear to be a common basis for the various sub-chapters. This is particularly evident in those sub-chapters which deal with more than one system, particularly where the chemistry, functional and safety requirements for those systems are very different. This means that the information provided varies significantly and there is often very detailed, non-safety-related or non-chemical-control-related information in the documents, which sometimes masks the key safety arguments. The need or usefulness of this information, particularly at PCSR level, should be reviewed.

135 In the interim between the issue of HPC PCSR2012 and the present NNB GenCo have continued with their development of the chemistry aspects of HPC. A brief summary is provided in my assessment, with the main conclusion being that NNB GenCo have

progressed in these areas in a satisfactory manner and I am content with the improvements being made.

136 Of the chemistry specific sub-chapters (5.5, 6.9, 9.6 and 10.7), I conclude that sub-chapter 9.6 is currently inadequate as presented. Sub-chapter 6.9 also need significant development. I have raised an issue within ONR's issues database, to ensure these matters are adequately addressed through routine future regulatory work.

137 However, I believe that the basis of an adequate safety case is present in the documents, but the presentation of it is poor at present. I am content that there are no fundamental safety issues or concerns, which are not covered by existing Assessment Findings from GDA of UK EPR™. I have raised an issue within ONR's issues database, to address a specific point related to the demineralised water systems at HPC. At present the site specific aspects of HPC have made little difference to the principal chemistry elements of the safety case, which is as I would expect and will allow NNB GenCo to make best use of fleet standardisation with EDF and other EPR reactors worldwide.

138 In terms of development of the safety case for HPC, aside from the developments expected as part of normal business by NNB GenCo (including incorporation of the final consolidated GDA PCSR (November 2012), resolution of GDA Assessment Findings and design development), the key expectations that this assessment has highlighted are:

- One of the key outputs from the safety case needs to be the limits and conditions necessary in the interests of safety. I would expect more clarity to be provided on these elements of the safety case, in line with ONR guidance. It should be made clear what chemistry parameters/specifications will be part of these, even if it is "*preliminary*" at this stage. (Note that this was done as part of the final consolidated GDA PCSR (November 2012) to some degree). **AF-UKEPR-RC-01** and **AF-UKEPR-RC-02** refer.
- It was noted that, while the "steady state" chemistry is reasonably well defined, the chemistry controls during transitions between different reactor states is less well documented. As some of these will be safety significant, these should also be documented in the PCSR, particularly any limits and controls necessary. **AF-UKEPR-RC-01** and **AF-UKEPR-RC-02** refer.
- The development of the secondary circuit chemistry regime and associated justifications need to be progressed. These were deemed site specific to some degree during GDA. **AF-UKEPR-RC-27** to **AF-UKEPR-RC-36** refer.
- The safety justification for boron control, particularly related to the use of enriched boric acid and associated recycling needs to be clarified in the safety case. **AF-UKEPR-RC-04** refers.

139 This submission should be recorded in the Integrated Intervention Strategy (IIS) database with a rating of 4 (yellow), below standard. This is based upon the recognition that, while the presentation of the safety case needs improvement, I remain content for this point in time and acknowledge that the Licensee is working to improve in this area.

140 To conclude, I am broadly satisfied with the claims, arguments and evidence laid down within the Licensee's safety case at this stage in the development of the design and safety case for HPC. However, I expect significant improvements to be made to the safety case at the next revision. In the longer term I would expect further refinements as the safety case moves towards commissioning and operations, where chemistry becomes more significant. I am content that the progress made by NNB GenCo in the reactor chemistry area supports the conclusion that these will be realised.

5.2 Recommendations

141 My recommendations are as follows.

- **Recommendation 1**: ONR to follow up the identified forward work activities not previously discussed with NNB GenCo, relevant to the reactor chemistry topic area, as part of the on-going intervention on reactor chemistry.

5.3 Issues Raised During the Assessment

142 As a consequence of my assessment of HPC PCSR2012, I have identified two issues for inclusion into the ONR issues database that need to be resolved, as appropriate. I conclude that the issues listed in Table 4 should be programmed during the forward programme of this reactor as normal regulatory business.

5.4 Impacted GDA Assessment Findings

143 There are no impacted Assessment Findings from GDA of UK EPR™.

144 However, a number of GDA Assessment Findings relate to the aspects discussed in this assessment. As such the licensee may wish to consider the comments made in this report as part of the resolution of these related Assessment Findings.

6 REFERENCES

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6 *Western European Nuclear Regulators' Association. Reactor Harmonization Group. WENRA Reactor Reference Safety Levels.* WENRA. January 2008. www.wenra.org.

7 *EPRI PWR Primary Chemistry Guidelines.* The latest version is available only to members, however earlier versions which contain much of the technical background are available at www.epri.com.

8 *VGB Guideline for the Water in Nuclear Power Stations with Light Water Reactors (PWR)*. VGB-R 401 J. VGB PowerTech Service GmbH Company, Essen.

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10 *Step 4 Reactor Chemistry Assessment of the EDF and AREVA UK EPR™ Reactor*. ONR Assessment Report ONR-GDA-AR-11-024. Revision 0. TRIM Ref. 2010/581508. www.hse.gov.uk/newreactors/reports/step-four/technical-assessment/ukepr-rc-onr-gda-ar-11-024-r-rev-0.pdf

11 *UK EPR GDA Step 4 Consolidated Pre-construction Safety Report*. Letter from UK EPR™ Project Front Office to ONR. Unique Number EPR00997N. 18 November 2011. TRIM Ref. 2011/552663.

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15 *GI-UKEPR-RC02 Action 1 – Final version of PCSR Sub-chapter 5.5*. Letter from UK EPR™ Project Front Office to ONR. Unique Number EPR01445N. 30 October 2012. TRIM Ref. 2012/423892.

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18 *Level 4 Reactor Chemistry Meeting with ONR / EA / NNB GenCo [Meeting no.7]*. ONR Intervention Report ONR-NNB-IR-13-033. Revision 0. TRIM Ref. 2013/297095. www.hse.gov.uk/nuclear/intervention-reports/2013/hinkley-point-c-13-033.htm

19 *Level 4 Reactor Chemistry Meeting with ONR / EA / NNB GenCo [Meeting no.8]*. ONR Intervention Report ONR-NNB-IR-13-068. Revision 0. TRIM Ref. 2013/435957.

Table 1

Relevant HPC PCSR2012 Sub-chapters Considered During the Assessment

Sub-chapter	Title	Reference	Issue	Change from March 2011 GDA PCSR
-	HPC PCSR 2012 Head Document	HPC-NNBOSL-U0-000-RES-000076	1.0	New
-	HPC PCSR2 Forward Work Activities	HPC-NNBOSL-U0-000-RES-000082	1.0	New
Chapter 5 - Reactor Coolant System And Associated Systems				
5.5	Reactor Chemistry	HPC-NNBOSL-U0-000-RES-000024	1.0	Updated
Chapter 6 - Containment And Safeguard Systems				
6.9	Containment and Safeguard Systems Chemistry Control	HPC-NNBOSL-U0-000-RES-000046	1.0	New
Chapter 9 - Auxiliary Systems				
9.2	Water Systems	HPC-NNBOSL-U0-000-RES-000053	1.0	Updated
9.6	Auxiliary Systems Chemistry Control	HPC-NNBOSL-U0-000-RES-000047	1.0	New
Chapter 10 - Steam and Power Conversion Systems				
10.2	Turbo-Generator Set	HPC-NNBOSL-U0-000-RES-000023	1.0	New
10.4	Other Features Of Steam And Power Conversion Systems	HPC-NNBOSL-U0-000-RES-000014	1.0	New
10.7	Secondary System Chemistry	HPC-NNBOSL-U0-000-RES-000011	1.0	Updated
Chapter 11 - Discharges And Waste/Spent Fuel				
11.2	Radioactive Waste Management Process and Strategy	HPC-NNBOSL-U0-000-RES-000056	1.0	Updated
11.4	Effluent And Waste Treatment Systems Design Architecture	HPC-NNBOSL-U0-000-RES-000012	1.0	Updated
11.5	Interim Storage Facilities And Disposability For UK EPR	HPC-NNBOSL-U0-000-RES-000026	1.0	Updated
Chapter 12 - Radiological Protection				
12.2	Definition of Radioactive Sources in the Primary Circuit	HPC-NNBOSL-U0-000-RES-000020	1.0	Updated
Chapter 18 - Human Factors And Operational Aspects				
18.2	Normal Operation	HPC-NNBOSL-U0-000-RES-000037	1.0	Updated
Chapter 19 – Commissioning				
19.1	Plant Commissioning Programme	HPC-NNBOSL-U0-000-RES-000018	1.0	New

Table 2

Relevant Safety Assessment Principles Considered During the Assessment

SAP	Title	Description
Engineering principles: Commissioning		
ECM. 1	Commission testing	Before operating any facility or process that may affect safety it should be subject to commissioning tests to demonstrate that, as built, the design intent claimed in the safety case has been achieved.
Engineering principles: Ageing and degradation		
EAD. 1	Safe working life	The safe working life of structures, systems and components that are important to safety should be evaluated and defined at the design stage.
EAD. 2	Lifetime margins	Adequate margins should exist throughout the life of a facility to allow for the effects of materials ageing and degradation processes on structures, systems and components that are important to safety.
EAD. 3	Periodic measurement of material properties	Where material properties could change with time and affect safety, provision should be made for periodic measurement of the properties.
EAD. 4	Periodic measurement of parameters	Where parameters relevant to the design of plant could change with time and affect safety, provision should be made for their periodic measurement.
Engineering principles: Integrity of metal components and structures		
EMC. 2	Use of scientific and technical issues	The safety case and its assessment should include a comprehensive examination of relevant scientific and technical issues, taking account of precedent when available.
EMC. 3	Evidence	Evidence should be provided to demonstrate that the necessary level of integrity has been achieved for the most demanding situations.
EMC. 13	Materials	Materials employed in manufacture and installation should be shown to be suitable for the purpose of enabling an adequate design to be manufactured, operated, examined and maintained throughout the life of the facility.
EMC. 16	Contamination	The potential for contamination of materials during manufacture and installation should be controlled to ensure the integrity of components and structures is not compromised.
EMC. 21	Safe operating envelope	Throughout their operating life, safety-related components and structures should be operated and controlled within defined limits consistent with the safe operating envelope defined in the safety case.
EMC. 22	Material compatibility	Materials compatibility for components should be considered for any operational or maintenance activities.
EMC. 24	Operation	Facility operations should be monitored and recorded to demonstrate compliance with the operating limits and to allow review against the safe operating envelope defined in the safety case.

Table 2

Relevant Safety Assessment Principles Considered During the Assessment

SAP	Title	Description
EMC. 25	Leakage	Means should be available to detect, locate, monitor and manage leakage that could indicate the potential for an unsafe condition to develop or give rise to a significant radiological effect.
Engineering principles: Safety systems		
ESS. 1	Requirement for safety systems	All nuclear facilities should be provided with safety systems that reduce the frequency or limit the consequences of fault sequences, and that achieve and maintain a defined safe state.
ESS. 2	Determination of safety system requirements	The extent of safety system provisions, their functions, levels of protection necessary to achieve defence in depth and required reliabilities should be determined.
ESS. 3	Monitoring of plant safety	Adequate provisions should be made to enable the monitoring of the plant state in relation to safety and to enable the taking of any necessary safety actions.
ESS. 4	Adequacy of initiating variables	Variables used to initiate a safety system action should be identified and shown to be sufficient for the purpose of protecting the facility.
ESS. 16	No dependency on external sources of energy	Where practicable, following a safety system action, maintaining a safe facility state should not depend on an external source of energy.
Engineering principles: Control of nuclear matter		
ENM. 1	Strategies for nuclear matter	A strategy (or strategies) should be made and implemented for the management of nuclear matter.
ENM. 2	Provisions for nuclear matter brought onto, or generated on, the site	Nuclear matter should not be generated on the site, or brought onto the site, unless sufficient and suitable arrangements are available for its safe management.
ENM. 3	Transfers and accumulation of nuclear matter	Unnecessary or unintended generation, transfer or accumulation of nuclear matter should be avoided.
ENM. 4	Control and accountancy of nuclear matter	Nuclear matter should be appropriately controlled and accounted for at all times.
ENM. 5	Characterisation and segregation	Nuclear matter should be characterised and segregated to facilitate its safe management.
ENM. 6	Storage in a condition of passive safety	When nuclear matter is to be stored on site for a significant period of time it should be stored in a condition of passive safety and in accordance with good engineering practice.
ENM. 7	Retrieval and inspection of stored nuclear matter	Storage of nuclear matter should be in a form and manner that allows it to be retrieved and, where appropriate, inspected.
Engineering principles: Reactor core		
ERC. 1	Design and operation of reactors	The design and operation of the reactor should ensure the fundamental safety functions are delivered with an appropriate degree of confidence for permitted operating modes of the reactor.

Table 2

Relevant Safety Assessment Principles Considered During the Assessment

SAP	Title	Description
ERC. 3	Stability in normal operation	The core should be stable in normal operation and should not undergo sudden changes of condition when operating parameters go outside their specified range.
ERC. 4	Monitoring of safety-related parameters	The core should be designed so that safety-related parameters and conditions can be monitored in all operational and design basis fault conditions and appropriate recovery actions taken in the event of adverse conditions being detected.
Engineering principles: Heat transport systems		
EHT. 4	Failure of heat transport system	Provisions should be made in the design to prevent failure of the heat transport system that could adversely affect the heat transfer process, or safeguards should be available to maintain the facility in a safe condition and prevent any release in excess of safe limits.
EHT. 5	Minimisation of radiological doses	The heat transport system should be designed to minimise radiological doses.
Radioactive Waste Management		
RW.2	Generation of radioactive waste	The generation of radioactive waste should be prevented or, where this is not reasonably practicable, minimised in terms of quantity and activity.

Table 3

Relevant Technical Assessment Guides Considered During the Assessment

Reference	Revision	Title
NS-TAST-GD-004	4	Fundamental principles
NS-TAST-GD-005	5	ONR guidance on the demonstration of ALARP (as low as reasonably practicable)
NS-TAST-GD-016	4	Integrity of metal components and structures
NS-TAST-GD-020	1	Containment for reactor plants
NS-TAST-GD-021	2	Containment for chemical plants
NS-TAST-GD-022	2	Ventilation
NS-TAST-GD-023	3	Control of processes involving nuclear matter
NS-TAST-GD-035	1	The limits and conditions for nuclear plant safety
NS-TAST-GD-037	2	Heat transport systems
NS-TAST-GD-038	3	Radiological protection
NS-TAST-GD-041	3	Criticality safety
NS-TAST-GD-051	3	The purpose, scope and content of nuclear safety cases
NS-TAST-GD-081	1	Safety aspects specific to storage of spent nuclear fuel
TBC	*1*	*Chemistry of operating civil reactors*[1]

[1] This TAG was draft during production of this assessment, but was expected to be issued before this report is finished.

Table 4

Issues Raised During the Assessment

Issue No.	Issue Title	Issue	Level	Who	Completion / Review Date
2108	Adequacy of the chemistry elements of the HPC safety case	The licensee shall review the chemistry elements of the safety case presented in HPC PCSR2012 and ensure that the consistency, visibility and clarity of chemistry related claims, arguments and evidence (or equivalent) is adequate.	4	[redacted] NNB GenCo	31 March 2016
2109	Safety functions of water treatment systems at HPC	The licensee shall review if safety claims are needed for the demineralised water treatment and distributions systems (SDA, SED and SER) for HPC.	4	[redacted] NNB GenCo	31 December 2015

Annex 1

<u>Detailed Comments on HPC PCSR2012 Sub-chapter 5.5 – Reactor chemistry</u> ➔

[redacted]

Annex 1

19 [redacted]

Annex 2

<u>Detailed Comments on HPC PCSR2012 Sub-chapter 6.9 – Containment and Safeguard Systems Chemistry Control</u>➔

[redacted]

Annex 3

<u>Detailed Comments on HPC PCSR2012 Sub-chapter 9.6 – Auxiliary Systems Chemistry Control</u>

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Annex 3

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Annex 4

Detailed Comments on HPC PCSR2012 Sub-chapter 10.7 – Secondary System Chemistry ➔

[redacted]

[redacted]

[redacted]

[redacted]

Annex 5

***Detailed Comments on HPC PCSR2012 Sub-chapter 18.2 – Normal Operations*➔**

[redacted]