ONR Assessment Report

Generic Design Assessment of the BWRX-300 – Step 2 Assessment of Chemistry

ONR Assessment Report

Project Name: Generic Design Assessment of the BWRX-300 – Step 2

Report Title: Step 2 Assessment of Chemistry

Authored by: Principal Inspector, ONR; Inspector, ONR

Assessment report reference: AR-01358

Project report reference: PR-01880

Report issue: 1

Published: December 2025

Document ID: ONRW-2126615823-7703

Executive summary

In December 2024, the Office for Nuclear Regulation (ONR), together with the Environment Agency and Natural Resources Wales, began Step 2 of the Generic Design Assessment (GDA) of the Boiling Water Reactor (BWR)X-300 design on behalf of GE Vernova Hitachi Nuclear Energy International LLC, United Kingdom (UK) Branch, the Requesting Party (RP).

This report presents the outcomes of my chemistry assessment of the BWRX-300 design as part of Step 2 of the ONR GDA. This assessment is based upon the information presented in the RP's safety, security, safeguards, and environment cases (SSSE), the associated revision 2 of the Design Reference Report and supporting documentation.

ONR's GDA process calls for an assessment of the RP's submissions, which increases in detail as the project progresses. The focus of my assessment in this step was to support ONR's decision on the fundamental adequacy of the BWRX-300 design and safety case, and the suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the design and generic safety, security and safeguards cases.

I targeted my assessment, in accordance with my assessment plan, at the areas that were fundamental to the acceptability of the design and methods for deployment in Great Britain (GB), benchmarking my regulatory judgements against the expectations of the expectations of ONR's Safety Assessment Principles (SAPs), Technical Assessment Guides (TAGs) and other guidance which ONR regards as relevant good practice, such as International Atomic Energy Agency (IAEA) safety, security and safeguards standards. Where appropriate, I have also considered how I could use relevant learning and regulatory conclusions from the UK ABWR GDA to inform my assessment of the BWRX-300

I targeted the following aspects in my assessment of the BWRX-300 SSSE:

- Reactor Coolant System (RCS) water chemistry, including the capability to control chemistry within developing limits and conditions necessary in the interests of safety.

- Chemistry in passive cooling systems (including the isolation condenser system (ICS) and passive containment cooling system (PCCS)).

- The RP's strategy for addressing accident chemistry, including development of design provisions for the mitigation of the consequences of an accident.

- The RP's approach to defining and justifying the source term for BWRX-300, including development using appropriate methods.

- The adequacy of the overall chemistry safety case, claims and arguments to, demonstrate that risks can be reduced so far as is reasonably practicable (SFAIRP).

Based upon my assessment, I have concluded the following:

- In relation to RCS chemistry, I judge this is aligned with the UK ABWR and represents relevant good practice based on previous ONR assessment. I judge improvements to feedwater system material selection and heater drains design will enable lower feedwater corrosion products. I consider that as part of the ongoing development of the BWRX-300 design and safety case, the designers of the BWRX-300 should substantiate the chemistry control systems.

- I have not identified any fundamental shortfalls related to chemistry in the ICS or PCCS. I judge that the designers of the BWRX-300 should provide additional evidence to justify chemistry selection for the ICS pools and equipment pool clean up capacity in future safety cases and as part of ongoing routine design development.

- I am satisfied with the methodology applied in deriving the BWRX-300 source term and comparison with UK ABWR. I consider the designers of the BWRX-300 should provide additional justification to demonstrate stellite reduction SFAIRP as part of ongoing routine design development.

- I judge that an adequate accident chemistry strategy for the BWRX-300 design has been developed, with requirements identified across the main topics of relevance to accident chemistry. I consider that as part of the ongoing routine development of the BWRX-300 design and safety case, the designers of the BWRX-300 should implement the accident chemistry strategy and substantiate accident chemistry mitigation measures.

- Where I have identified gaps with relevant good practice or requirements for further work over the course of my assessment, I am satisfied these have been appropriately captured with forward actions that the designers of the BWRX-300 should progress. This includes provision of a chloride ingress protection system (CIPS) and implementation of the accident chemistry strategy.

- The scope, structure and content of the safety case meets my expectations for two step GDA from a chemistry perspective. I judge however that future safety cases supporting BWRX-300 developments should provide a consistent use of terminology for chemistry claims in the PSR.

Overall, based on my assessment to date I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design; noting that any decision to permission a BWRX-300 will require further assessment (in either a future Step 3 GDA or during site specific activities) of suitable and sufficient supporting evidence that can substantiate the claims and proposals made in the GDA Step 2 submissions.

List of abbreviations

ALARP	As Low As Reasonably Practicable
ABWR	Advanced Boiling Water Reactor
ALARA	As Low as Reasonably Achievable
ANS	American Nuclear Society
BIS	Boron Injection System
BL	Baseline
BWR	Boiling Water Reactor
CFD	Condensate Filters and Demineralizers System
CFS	Condensate and Feedwater and Heating System
CIPS	Chloride Ingress Protection System
CNSC	Canadian Nuclear Safety Commission
CUW	Reactor Water Cleanup System
DAC	Design Acceptance Confirmation
DRR	Design Reference Report
DZO	Depleted Zinc Oxide
EPRI	Electric Power Research Institute
ESBWR	Economic Simplified Boiling Water Reactor
FPC	Fuel Pool Cooling and Cleanup System
GB	Great Britain
GDA	Generic Design Assessment
GEZIP	GE Zinc Injection Passivation
GVHA	GE Vernova Hitachi Nuclear Energy Americas LLC
HWC	Hydrogen Water Chemistry
IAEA	International Atomic Energy Agency
ICC	Isolation Condenser Cooling and Cleanup System
ICS	Isolation Condenser System
LCO	Limits and Conditions of Operation
LfE	Learning from Experience
MDSL	Master Document Submission List
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NRW	Natural Resources Wales
OLNC™	On-Line Noble Chem
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PA	Protected Area
PCCS	Passive Containment Cooling System
PER	Preliminary Environment Report
PSAR	Preliminary Safety Analysis Report
PSR	Preliminary Safety Report
RCS	Reactor Coolant System
RGP	Relevant Good Practice
RITE	Risk Informed, Targeted Engagements
RO	Regulatory Observation
RP	Requesting Party

RPV	Reactor Pressure Vessel
RQ	Regulatory Query
SAP	Safety Assessment Principle(s)
SFAIRP	So far as is reasonably practicable
SFP	Spent Fuel Pool
SLC	Standby Liquid Control System
SSSE	Safety, Security, Safeguards and Environment Cases
SSC	Systems, Structures and Components
SSG	Specific Safety Guide
TAG	Technical Assessment Guide(s)
TSC	Technical Support Contractor
UK	United Kingdom
US	United States of America
WENRA	Western European Nuclear Regulators’ Association

Contents

1. Introduction

1. This report presents the outcome of my chemistry assessment of the Boiling Water Reactor (BWR)X-300 design as part of Step 2 of the Office for Nuclear Regulation (ONR) Generic Design Assessment (GDA). My assessment is based upon the information presented in the Safety, security, safeguards and environment cases (SSSE) head document (ref. [1]), specifically chapters 1, 5, 6, 10, 12, 22, 23, and 27 (refs. [2], [3], [4], [5], [6], [7], [8] and [9]) the associated revision of the Design Reference Report (DRR) (ref. [10]) and supporting documentation.

2. Assessment was undertaken in accordance with the requirements of the ONR's Management System and follows ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [11]) and ONR's risk informed, targeted engagements (RITE) guidance (ref. [12]. The ONR Safety Assessment Principles (SAPs) (ref. [13]), together with supporting Technical Assessment Guides (TAGs) (ref. [14]), have been used as the basis for this assessment.

3. This is a Major report as per ONR's guidance on the production of reports (ref. [15]).

1.1. Background

4. The ONR's GDA process (ref. [16]) calls for an assessment of the Requesting Party's (RP) submissions with the assessments increasing in detail as the project progresses. This GDA will be finishing at Step 2 of the GDA process. For the purposes of the GDA, GE Vernova Hitachi Nuclear Energy International LLC, United Kingdom (UK) Branch, is the RP. GE Vernova Hitachi Nuclear Energy Americas LLC (GVHA) is a provider of advanced reactors and nuclear services and is the designer of the BWRX-300. GVHA is headquartered in Wilmington, North Carolina, United States of America (US).

5. In Step 1, and for the majority of Step 2, the RP was known as GE-Hitachi Nuclear Energy International LLC, UK Branch, and GVHA as GE-Hitachi Nuclear Energy Americas LLC. The entities formally changed names in October 2025 and July 2025 respectively. The majority of the submissions provided by the RP during GDA were produced prior to the name change, and thus the reference titles in Section 6 of this report reflects this.

6. In the UK, the RP has been supported by its supply chain partner, Amentum, who has assisted the RP in the development of the UK-specific chapters of the SSSE, and other technical documents for the GDA.

7. In January 2024 ONR, together with the Environment Agency and Natural Resources Wales (NRW) began Step 1 of this two-Step GDA for the generic BWRX-300 design.

8. Step 1 is the preparatory part of the design assessment process and is mainly associated with initiation of the project and preparation for technical assessment in Step 2. Step 1 completed in December 2024. Step 2 is the first substantive technical assessment step, and began in December 2024 and will complete in December 2025.

9. The RP has stated that at this time it has no plans to undertake Step 3 of GDA and obtain a Design Acceptance Confirmation (DAC). It anticipates that any further assessment by the UK regulators of the BWRX-300 design will be on site-specific basis and with a future licensee.

10. The focus of ONR's assessment in Step 2 was:

- The fundamental adequacy of the design and safety, security, and safeguards cases; and
- The suitability of the methodologies, approaches, codes, standards, and philosophies which form the building blocks for the design and cases.

11. The objective is to undertake an assessment of the design against regulatory expectations to identify any fundamental safety, security or safeguards shortfalls that could prevent ONR permissioning the construction of a power station based on the design.

12. Prior to the start of Step 2 I prepared a detailed Assessment Plan for Chemistry (ref. [17]). This has formed the basis of my assessment and was also shared with the RP to maximise openness and transparency.

13. This report is one of a series of assessments which support ONR's overall judgements at the end of Step 2 which are recorded in the Step 2 Summary Report (ref. [18]) and published on the regulators' website.

1.2. Scope

14. The assessment documented in this report is based upon the SSSE for the BWRX-300 (refs. [1], [2], [19], [20], [21], [3], [4], [22], [23], [24], [25], [5], [26], [6], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [7], [8], [45], [46], [47], [9]), [48]).

15. The RP's GDA scope has been agreed between the regulators and the RP during Step 1. This is documented in an overall Scope of Generic Design Assessment report (ref. [49]). This is further supported by its DRR (ref. [10]) and the master document submission list (MDSL) (ref. [50]). The GDA scope report documents the submissions which were provided in each topic area during Step 2 and provides a brief overview of the physical and functional scope of the Nuclear Power Plant (NPP) that is proposed for consideration in the GDA. The DRR provides a list of the systems, structures and components (SSCs) which are included in the scope of the GDA, and their relevant GDA reference design documents.

16. The RP has stated it does not have any current plans to undertake GDA beyond Step 2. This has defined the boundaries of the GDA and therefore of my own assessment.

17. The GDA scope includes the Power Block (comprising the Reactor Building, Turbine Building, Control Building, Radwaste Building, Service Building, Reactor Auxiliary Structures) and Protected Areas (PAs) as well as the balance of plant. It includes all modes of operation.

18. The regulatory conclusions from GDA apply to everything that is within the GDA scope. However, ONR does not assess everything within it, or all matters to the same level of detail. This applies equally to my own assessment, and I have followed ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [11]) and ONR's guidance on Risk Informed, Targeted Engagements (ref. [12]).

19. As appropriate for Step 2 of the GDA, the RP has not submitted information for all aspects within the GDA Scope during Step 2. The RP confirmed in Step 1 the description of chemistry control for fluid systems is presented in the following systems, only:

- Reactor Coolant System (RCS).
- Spent Fuel Pool (SFP).
- Plant Cooling Water.
- Passive Cooling Systems.
- Isolation Condenser System (ICS).
- Passive Containment Cooling System (PCCS).
- Boron Injection System (BIS).
- Off-gas System Catalytic Recombiner.

20. My assessment has considered the following aspects:

- RCS water chemistry – the RP's developing safety justification for the operating chemistry, including adequacy of control systems to deliver the specified chemistry.
- Passive cooling systems – the consideration of chemistry of passive cooling systems to enable delivery of their safety functions, with focus on the ICS and PCCS
- Accident chemistry – the RP's demonstration that an adequate strategy exists to address accident chemistry, including design decisions regarding mitigation of the consequences of an accident.

- Source term – the adequacy of the RP's approach to defining and justifying the source term, including development using appropriate methods, covering all appropriate systems and sources of radioactivity, and that the RP appropriately integrate this into the safety case.

- The adequacy of the overall chemistry safety case as it develops, focussing on the adequacy of the claims and arguments and development of the demonstration that chemistry can reduce risks so far as is reasonably practicable (SFAIRP).

2. Assessment standards and interfaces

21. The primary goal of the GDA Step 2 assessment is to reach an independent and informed judgment on the adequacy of the RP's SSSE for the reactor technology being assessed.

22. ONR has a range of internal guidance to enable Inspectors to undertake a proportionate and consistent assessment of such cases. This section identifies the standards which have been considered in this assessment. This section also identifies the key interfaces with other technical topic areas.

2.1. Standards

23. Our ONR SAPs (ref. [16]) constitute the regulatory principles against which the RP's case is judged. Consequently, the SAPs are the basis for ONR's assessment and have therefore been used for the Step 2 assessment of the BWRX-300.

24. The International Atomic Energy Agency (IAEA) safety standards (ref. [51]) and nuclear security series (ref. [52]) are a cornerstone of the global nuclear safety and security regime. They provide a framework of fundamental principles, requirements, and guidance. They are applicable, as relevant, throughout the entire lifetime of facilities and activities.

25. Furthermore, ONR is a member of the Western European Nuclear Regulators Association (WENRA). WENRA has developed Reference Levels (ref. [53]), which represent good practices for existing nuclear power plants, and Safety Objectives for new reactors (ref. [54]).

26. The relevant SAPs, IAEA standards and WENRA reference levels are embodied and expanded on in the TAGs (ref. [14]). The TAGs provide the principal means for assessing the chemistry aspects in practice.

27. The key guidance is identified below and referenced where appropriate within Section 4 of this report. Relevant good practice (RGP), where applicable, has also been cited within the body of this report.

2.1.1. SAPs

28. The key SAPs applied within my assessment are:

- ECH.1 – to assess the adequacy of the RP's safety case from a chemistry perspective and the safety case addresses all chemistry effects important to safety by applying a systematic process.
- ECH.2 – to assess whether the safety case demonstrates an appropriate balance for safety where the effects of different chemistry parameters conflict with one another.
- ECH.3 – to assess whether the safety case identifies suitable and sufficient systems, processes and procedures to maintain chemistry parameters within the limits and conditions.
- ECH.4 – to assess whether suitable and sufficient systems exist for monitoring, sampling and analysis so that all chemistry parameters important to safety are properly controlled.
- EHT.4 – to assess the provisions made in the design to prevent failures of the heat transport system
- EHT.5 – to assess the design, construction and operation of the facility and the choice of heat transfer fluid should minimise the amount of radioactive material in the fluid.

29. A list of the SAPs used in this assessment is recorded in Appendix 1.

2.1.2. TAGs

30. The following TAGs have been used as part of this assessment:

- NS-TAST-GD-005 – Regulating duties to reduce risks As Low As Reasonably Practicable (ALARP) (ref. [55]).
- NS-TAST-GD-051 – The purpose, scope, and content of safety cases (ref. [56]).
- NS-TAST-GD-088 – Chemistry of Operating Civil Nuclear Reactors (ref. [57]).
- NS-TAST-GD-089 – Chemistry Assessment (ref. [58]).
- NS-TAST-GD-096 - Guidance on Mechanics of Assessment (ref. [11]).

2.1.3. National and international standards and guidance

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

- IAEA, Chemistry Programme for Water Cooled Nuclear Power Plants, Specific Safety Guide (SSG) No. SSG-13 (ref. [59]). This safety guide contains relevant guidance and international good practice and is applicable to the development of new chemistry programmes.

2.2. Integration with other assessment topics

32. To deliver the assessment scope described above I have worked closely with a number of other topics (including the Environment Agency and NRW assessors) to inform my assessment. Similarly, other assessors sought input from my assessment. These interactions are key to the success of GDA to prevent or mitigate any gaps, duplications, or inconsistencies in ONR's assessment.

33. The key interactions with other topic areas were:

- I assessed the effects of the operating chemistry on susceptibility to material degradation mechanisms, supporting structural integrity assessment of the case for the integrity of metallic components and structures.

- I provided input to the cladding corrosion and crud aspects of the fuel and core assessment, including the effects of the RCS water chemistry on these aspects.

- I provided input in areas where chemistry effects or requirements were important to fault analysis or severe accidents.

- I led regarding normal operation radiological source terms, collaborating with a team of inspectors and assessors, (Environment Agency, radiological protection, and nuclear liabilities regulation (NLR)) to assess the adequacy of the methodology for deriving and justifying the normal operation source term.

2.3. Use of technical support contractors

34. During Step 2 I have not engaged Technical Support Contractors (TSCs) to support my assessment of the Topic aspects of the BWRX-300 GDA.

3. Requesting Party's submission

35. The RP submitted the SSSE at the start of Step 2 in four volumes that integrate environmental protection, safety, security, and safeguards. This was accompanied by a head document (ref. [1]), which presents the integrated GDA environmental, safety, security, and safeguards case for the BWRX-300 design.

36. All four volumes were subsequently consolidated to incorporate any commitments and clarifications identified in regulatory engagements, regulatory queries (RQs), and regulatory observations (ROs), and were resubmitted in July 2025. This consolidated revision is the basis of the regulatory judgements reached in Step 2.

37. This section presents a summary of the RP's safety case for chemistry. It also identifies the documents submitted by the RP which have formed the basis of my Step 2 assessment of the BWRX-300 design.

3.1. Summary of the BWRX-300 Design

38. The BWRX-300 is a single unit, direct-cycle, natural circulation, boiling water reactor with a power of ~870 MW (thermal) and a generating capacity of ~ 300 MW (electrical) and is designed to have an operational life of 60 years. The RP claims the design is at an advanced concept stage of development and is being further developed during the GDA in parallel with the RP's SSSE.

39. The BWRX-300 is the tenth generation of the boiling water reactor (BWR) designed by GVHA and its predecessor organisations. The BWRX-300 design builds upon technology and methodologies used in its earlier designs, including the Advanced Boiling Water Reactor (ABWR), Simplified Boiling Water Reactor (SBWR) and the Economic Simplified Boiling Water Reactor (ESBWR). The ABWR has been licensed, constructed and is currently in operation in Japan, and a UK version of the design was assessed in a previous GDA with a view to potential deployment at the Wylfa Newydd site. Neither the SBWR or ESBWR have been built or operated.

40. The BWRX-300 reactor core houses 240 fuel assemblies and 57 control rods inside a steel reactor pressure vessel (RPV). It uses fuel assemblies (GNF2) that are already currently widely used globally (ref. [21]).

41. The reactor is equipped with several supporting systems for normal operations and a range of safety measures are present in the design to provide cooling, control criticality and contain radioactivity under fault conditions. In line with the RP's design philosophy, the BWRX-300 uses natural circulation and passive cooling rather than active components.

42. Of importance to chemistry, the BWRX-300 employs a fully cascaded feedwater heater drains system. The system returns all extracted steam to the condenser hot well, resulting in 100% of condensate passing through the Condensate Filters and Demineralizers System (CFD). Previous BWRs (including the UK ABWR, ref. [60]) operated with “forward pumped” feedwater heater drains, with a portion of condensate bypassing clean up. Additionally, the Condensate and Feedwater and Heating System (CFS) features a predominantly stainless steel construction, with previous BWRs applying carbon steel. Combined, these differences should result in lower levels of corrosion products fed forward to the reactor core.

43. A further notable difference in BWRX-300 to operating BWRs is there is no dedicated clean up performed by the reactor water cleanup system (CUW) as is the case for UK ABWR. The CUW instead reroutes 1% of feedwater flow from two lines in the lower plenum of the RPV upstream of the CFD system. Also, of relevance to RCS chemistry control is that the RPV of BWRX-300 also contains an elongated “chimney” section in comparison to existing BWRs. This enables natural convection and passive cooling in the event of a reactor trip.

44. The BWRX-300 includes passive core and containment cooling systems, the ICS and PCCS, respectively. The ICS transfers heat from the RCS to the environment via heat exchangers in ICS pools. ICS return lines are isolated when not in operation. The PCCS transfers heat from in containment heat exchangers to the equipment pool. This equipment pool connects to the reactor cavity pool, which is in direct contact with the containment head. The UK ABWR containment head is “dry” by comparison.

3.2. BWRX-300 Case Approach and Structure

45. The RP has submitted information on its strategy and intentions regarding the development of the SSSE (ref. [61], [62], [63], [64]). This was submitted to ONR during Step 1.

46. The RP has submitted a SSSE for the BWRX-300 that claims to demonstrate that the standard BWRX-300 can be constructed, operated, and decommissioned on a generic site in Great Britain (GB) such that a future licensee will be able to fulfil its legal duties for activities to be safe, secure and will protect people and the environment. The SSSE comprises a Preliminary Safety Report (PSR) which also includes information on its approach to safeguards and security, a security assessment, a Preliminary Environment Report (PER), and their supporting documents.

47. The format and structure of the PSR largely aligns with the IAEA guidance for safety cases, SSG-61 (ref. [65]), supplemented to include UK specific chapters such as Structural Integrity and Chemistry. The RP has also provided a chapter on ALARP, which is applicable to all safety chapters. The RP has stated that the design and analysis referenced in the PSR is

consistent with the March 2024 Preliminary Safety Analysis Report (PSAR) submitted to the US Nuclear Regulatory Commission (NRC).

3.3. Summary of the RP's case for Chemistry

48. The chemistry PSR Chapter 23 (ref. [8]) presents three high level claims for chemistry:

- Ageing and degradation mechanisms will be identified and assessed in the design (claim 2.1.5)
- RGP has been considered across all disciplines (2.4.1)
- Operational Experience (OPEX) and Learning from Experience (LfE) has been considered across all disciplines (claim 2.4.2)

49. The RP presents more specific chemistry requirements throughout PSR Chapter 23. I consider these to represent chemistry claims, in line with the interpretation in NS-TAST-GD-089 (ref. [58]). I judge that requirements are more aligned with arguments presented by the RP (discussed in section 3.3.5 below). I have grouped the aspects covered by the BWRX-300 chemistry safety case under five headings, which are summarised as follows.

3.3.1. RCS Water Chemistry

50. The RP presents three requirements for RCS water chemistry. These are to minimise fuel pin leaks by maintaining clad integrity; maintain structural integrity to all parts of the RCS and ancillary systems; and reduce the radioactive source term. In terms of chemical addition, this involves:

- Hydrogen Water Chemistry (HWC) - Addition of hydrogen to the feedwater, resulting in excess hydrogen and therefore lower oxidants in the reactor coolant, for mitigation of intergranular stress corrosion cracking .
- On-Line Noble Chem (OLNC™) – Periodic addition of platinum to achieve low dissolved oxygen and surface potentials on BWR wetted surfaces.
- Zinc Injection, formally called GE Zinc Injection Passivation (GEZIP) – The addition of Depleted Zinc Oxide (DZO) into the feedwater system to reduce Cobalt-60 deposition on out of core components.

51. As detailed above, 100% of condensate passes via the CFD, with rerouting of 1% feedwater in the lower reactor plenum to the CFD via the CUW to provide chemistry control. The PSR presents a high-level view of chemistry control in reactor water across all modes.

52. The PSR presents control parameters across the reactor water and ancillary systems. This is supported by tier 2 submissions including water chemistry Guidelines (ref. [66]) and specifications (ref. [67]).

3.3.2. Passive Safety Systems

53. Related to the ICS, the RP presents two requirements for minimisation of corrosion of pipework and heat exchangers to ensure system integrity, safety function and achieve design life targets. PCCS requirements include minimisation of corrosion of PCCS pipework in contact with the equipment pool water to ensure system integrity, safety function and achieve design life targets. The RP also identifies requirements for minimising corrosion of the containment closure head in contact with the reactor cavity water to maintain containment integrity.

54. The Isolation Condenser Cooling and Cleanup System (ICC) provides clean-up capability for the ICS pools, maintaining demineralised water conditions. The ICC includes two identical, 50% capacity trains, each equipped with a centrifugal pump and frame-and-plate heat exchanger to transfer energy from the ICS pools to the Plant Cooling Water system. A single skid-mounted demineraliser to remove soluble impurities from the ICS pool water is available and equipped with a dosing pot for injecting chemicals for corrosion and biological control into the process fluid.

55. The Fuel Pool Cooling and Cleanup System (FPC) provides clean up capability for the PCCS equipment pool, maintaining demineralised water conditions. This connects to the reactor cavity pool. The FPC can use two 100% capacity pumps. The pumps discharge to individual FPC trains with 100% particulate filtration and a single deep bed demineralizer capable of processing 50% of either the A or B train. Each train has two 50% capacity shell and tube heat exchangers cooled by the PCW system.

3.3.3. Normal Operation Source Term

56. As noted for RCS chemistry, the RP presents the requirement that RCS water chemistry will reduce the radioactive source term by minimising dose rates to workers and the public, radioactive waste accumulations and releases of radioactivity to the environment.

57. PSR Chapter 23 sets out the methodology to produce realistic and design basis normal operation source terms for the primary circuit (ref. [8]). This is based on the American Nuclear Society (ANS) ANSI/ANS-18.1-2020 standard (ref. [68]) and GVHA fuel clad defect model, respectively. The ANSI/ANS-18.1-2020 standard is based on OPEX from 10 anonymised US BWRs, with adjustment factors applied to account for plant differences including power output and CUW capacity. The RP highlights positive material selection (replacement of carbon steel downstream of the CFD with

stainless steel) in the CFS and chemistry control (addition of DZO) in minimising the source term.

58. Notably, the RP has also conducted a comparison of the realistic and design basis BWRX-300 source term with the UK ABWR. The RP uses this comparison to support their view that the realistic source term is conservative and design basis source term is appropriate.

3.3.4. Accident Chemistry

59. The RP identifies six chemistry requirements related to accident chemistry in PSR Chapter 23 (Ref. [8]). These include requirements to minimise activity release (dry and wet scrubbing) during accident scenarios; hydrogen management (in and ex-vessel); and criticality control in the event of control rod injection failure. This aligns to the requirements set out in PSR Chapter 15 on Safety Analysis [29].

60. Minimisation of activity release from the plant is achieved by aerosol deposition and active scrubbing through Storage/Filter Pools. Hydrogen management is delivered in containment by nitrogen inerting (in-vessel) and corium shield material selection and pedestal water injection (ex-vessel). Finally, beyond design basis shutdown is achieved by injection of enriched sodium pentaborate decahydrate solution via the BIS.

61. Further for accident chemistry, the RP highlights ongoing work due to BWRX-300 design development and completion of deterministic fault analyses. The RP recognises that additional chemistry requirements may arise. This includes the potential requirement for pH buffering of water volumes, filtered containment venting and application of passive autocatalytic recombiners.

3.3.5. Reduction of Risks ALARP

62. The RP's holistic high-level ALARP justification of the BWRX-300 is in PSR Chapter 27: ALARP Evaluation (ref. [9]). In respect of chemistry, it is stated in PSR Chapter 23 (ref. [8]) *"It is important to note that nuclear safety risks cannot be demonstrated to have been reduced ALARP within the scope of a 2-Step GDA. However, the design aspects, as set out in this chapter will effectively contribute to the development of a future ALARP position."*

63. The RP claims in PSR Chapter 23 that safety risks are ALARP (claim 2.4). The RP underpins this with claims related to consideration of RGP and OPEX (claim 2.4.1 and 2.4.2 respectively). The subsequent arguments support the RPs claims:

- 2.4.1 a – The BWRX-300 chemistry regime will contribute to the maintenance of integrity of the reactor coolant circuit SSCs by chemical dosing and impurity control (both within specified limits), and by material selection.

- 2.4.1 b – The BWRX-300 chemistry will contribute to the maintenance of integrity of the fuel by chemical dosing and impurity control (both within specified limits), and by material selection.
- 2.4.1 c – The BWRX-300 chemistry will contribute to the maintenance of a range of other SSCs by chemical dosing, impurity control, and material selection.
- 2.4.1 d – The BWRX-300 chemistry regime will ensure the source term radiological dose to the worker and public is ALARP by optimising material selection, operating chemistry, and operating practices.
- 2.4.1 e – The BWRX-300 chemistry regime will ensure the source term reduces waste accumulation and routine discharges by optimising material selection, operating chemistry, and operating practices.
- 2.4.2 a – The BWRX-300 chemistry regime builds on the historical evolution of BWR chemistry developed over decades of operation.

64. The RP asserts that the management and control of chemistry in the various systems of the BWRX-300 is important for the safe and reliable operation of the plant and to minimise its environmental effects. The chief aim is to achieve continued structural integrity of the structures, systems, and components, minimise fuel failures and limit the generation and transport of radioactive material within the plant. By reducing the source term SFAIRP, doses to workers and the public will be minimised in addition to minimisation of radioactive waste accumulation.

65. The RP notes the BWRX-300 chemistry regime builds on OPEX and RGP obtained from the historical evolution of BWR chemistry developed over decades of operation. The RP asserts the chemistry regime is bespoke to the BWRX-300 design and is an integral part of maintaining plant condition. Specifically, the RP states chemical dosing and impurity control within specified limits maintains integrity of the reactor coolant circuit SSCs and the fuel. For other SSCs, the RP states the chemistry regime will also contribute to the maintenance of integrity by combinations of chemical dosing, impurity control and materials selection. The RP adds the BWRX-300 chemistry regime will ensure the source term radiological dose to the workers and public is minimised. The RP states the chemistry regime achieves these objectives by optimising material selection and operating practices.

3.4. Basis of assessment: RP's documentation

66. The principal documents that have formed the basis of my chemistry assessment of the SSSE are:

- PSR Chapter 23 Reactor Chemistry (ref. [8])
- BWRX-300 Primary Water Chemistry Guidelines (ref. [66])

- BWRX-300 Water Quality: Technical Requirements Specifications (ref. [67])
- BWRX-300 Operating Water Chemistry Regime (ref. [69])

3.5. Design Maturity

67. My assessment is based on revision 3 of the DRR (ref. [10]). The DRR presents the baseline design for GDA Step 2, outlining the physical system descriptions and requirements that form the design at that point in time.

68. The reactor building and the turbine building, along with most of the significant SSCs are housed within the ‘power block.’ The power block also includes the radwaste building, the control building and a plant services building. For security, this also includes the PA boundary and the PA access building.

69. The GDA Scope Report (ref. [49]) describes the RP’s design process that extends from baseline (BL) 0 (where functional requirements are defined) up to BL 3 (where the design is ready for construction).

70. In the March 2024 design reference, SSCs in the power block are stated to be at BL1. BL1 is defined as:

- Established system interfaces.
- (included) in an integrated 3D model.
- Instrumentation and control aspects have been modelled.
- Undertaking of deterministic and probabilistic analysis.
- System descriptions developed for the primary systems.

71. The balance of plant remains at BL0 for which only plant requirements have been established, and SSC design remains at a high concept level.

4. ONR assessment

4.1. Assessment strategy

72. The objective of my GDA Step 2 assessment was to reach an independent regulatory judgement on the fundamental aspects of the BWRX-300 design, relevant to chemistry as described in sections 1 and 3 of this report. My assessment strategy is set out in this section and defines how I have chosen which matters to target for assessment. My assessment is consistent with the delivery strategy for the BWRX-300 GDA (ref. [70]).

73. GVHA is currently engaging with regulators internationally, including the US NRC and the Canadian Nuclear Safety Commission in Canada (CNSC). It is proposing a standard BWRX-300 design for global deployment with minimal design variations from country to country. My assessment takes cognisance of work undertaken by overseas regulators where appropriate.

74. Whilst there is no operating BWR plant in the UK, ONR has previously performed a four-step GDA on the Hitachi-GE UK ABWR (ref. [60]). I have taken learning from this previous activity, targeting my assessment on those aspects of the BWRX-300 which are novel or specific to this design. I have not looked to reassess inherent aspects of BWR technology which were considered in significant detail for the UK ABWR and judged to be acceptable.

75. My assessment focussed on the main themes of relevance to chemistry. These were protection of structural materials, maintaining fuel integrity and performance, delivery of passive cooling functions, minimisation of out of core radiation fields and minimisation of releases during fault and accident conditions.

76. I chose to target areas where I considered that justification and scrutiny of the design was appropriate due to factors such as novelty, as well as those which I judged to be the most relevant to safety. This targeting approach supports my overall Step 2 assessment objective of evaluating the design against regulatory expectations to identify any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the design.

77. The aspects of the RPs safety case that I focussed my assessment on were set out in my assessment plan, produced prior to the start of Step 2 (ref. [17]).

4.2. Assessment Scope

78. My assessment scope and the areas I have chosen to target for my assessment are set out in this section. This section also outlines the submissions that I have sampled, the standards and criteria that I will judge against and how I have interacted with the RP and other assessment Topics.

79. My assessment scope is consistent with the GDA scope agreed between the regulators and the RP during Step 1 and detailed in Section 1.2 of this report. I have targeted my assessment within this scope.

80. In line with the objectives for Step 2, I have undertaken a broad review of the highest level, fundamental claims and supporting arguments related to chemistry. To support this, I have sampled a targeted set of the claims or arguments as set out below. Where applicable, I have also sampled the evidence available to support any claims and arguments.

81. In order to fulfil the aims for the Step 2 assessment of the BWRX-300, I have assessed the following items, which I consider important:

- RCS water chemistry – I have examined the RP’s safety justification for the operating chemistry in the RCS and availability of adequate control systems. I targeted this due to novelty of the elongated RPV, CUW, and ICS system design in BWRX-300, and absence of a chloride ingress protection system (CIPS). This has required engagement with structural integrity and fuel and core specialists.

- Passive cooling – I have reviewed the consideration of chemistry within passive cooling systems, such that these are able to perform their safety functions for the BWRX-300 design life. This has included the ICS and PCCS which are novel to BWRX-300. This has required engagement with structural integrity specialists.

- Source terms – I have considered the RP’s approach to defining and justifying the normal operational source term. I targeted this to gain confidence about expected levels of activity, and therefore impact upon radiation protection, radioactive waste production and discharges. Engagement has therefore occurred with radiation protection, nuclear liabilities, and environmental specialists.

- Accident chemistry – I have assessed the adequacy of the RP’s strategy for accident chemistry. This explored the RPs approach to the main accident chemistry topics of fission product retention, management of flammable gases and in-vessel retention. This has required engagement with severe accident and fault studies specialists.

- The adequacy of the overall chemistry safety case, with focus on the adequacy of claims and arguments - I targeted this to ensure the safety case has an appropriate scope, structure, relevance and is consistent with relevant standards to support the RP's submitted design for GDA and future users.

4.3. Assessment

4.3.1. RCS Water Chemistry

82. SAP ECH.1 describes ONR’s expectation that safety cases should identify and analyse how chemistry can impact safety in normal operations and fault conditions. ECH.2 also describes the need for a balance where chemical parameters may conflict, while ECH.3 presents expectations for suitable and sufficient systems to enable control of chemistry. Similarly, EHT.4 and EHT.5 expect that the coolant within heat transport systems should minimise the potential for radioactivity accumulation or transport within the plant (ref. [13]). I therefore sampled the RP’s safety case documentation that describes the RCS chemistry regime for BWRX-300.

83. The RP presents three requirements for RCS chemistry (ref. [8]). These are to minimise fuel pin leaks by maintaining cladding integrity; maintain structural integrity to all parts of the reactor coolant circuit and ancillary systems; and reduce the radioactive source term.

84. The RP proposes HWC, OLNC™ and DZO for the BWRX-300 to deliver chemistry requirements (ref. [8]). This is consistent with UK ABWR (ref. [60]), ONR TAGs (ref. [57]) and based on Electric Power Research Institute (EPRI) guidelines (ref. [66]). I therefore judge this meets RGP, given previous ONR assessment and acceptance of this regime. The RP recognises the need to balance impacts of HWC in respect of increased main steam line dose rates from N-16 production through OLNC™ (to reduce required levels of hydrogen) in line with the expectations of ECH.2. Positively, I note the RP has given high level consideration to design differences between BWRX-300 and operating BWRs, including absence of a dedicated CUW system and reliance on 100 % treatment of condensate via the CFD system (ref. [71], RQ-01720 relates). I also note the development of limits and conditions necessary in the interest of safety for both reactor and feedwater across a number of modes in PSR Chapter 23 (ref. [8] and [71], RQ-02006 relates). I am therefore satisfied the RP is developing the safety case appropriately to meet the expectations of ECH.1 and ECH.2.

85. Pertinent to fuel integrity, the RP highlights off-gas monitoring of noble gases (ref. [71], RQ-01719 and RQ-02006 relate) to detect fuel failures, with forward action PSR23-420 to further define technical specifications related to radiochemistry. Related to crud, the RP recognises potential implications of elevated iron with an assertion that BWRX-300 will control iron below 1 ppb. The RP notes potential concerns that extremely low iron concentrations are responsible for increased cobalt in the coolant, however asserts this is no longer considered an issue due to transition to more corrosion resistant materials and greatly reduced flow accelerated corrosion issues. Chapter 23 of the PSR includes a forward action (PSR23-132) to define and justify action levels for iron (ref. [8]). I judge that the limits and conditions of operation (LCO) presented in chapter 23 of the PSR for expected ranges for iron in the feed water are currently consistent with UK ABWR. Therefore, I am satisfied that this meets the expectations of ECH.1. Chapter 23 of the PSR does not present a specific prediction of the expected levels of crud in BWRX-300. The RP asserts however that this is anticipated to be similar or lower to existing BWRs, on the basis of improved material selection in the feed system, cascaded feedwater heater drains and 100 % feed water polishing (ref. [71], RQ-02007 relates). I accept that fuel corrosion and crud is unlikely to be more onerous than existing BWRs, and I judge the chapter 23 of the PSR meets the expectations of SAP ECH.1, ECH.2, EHT.4 and EHT.5. However, I consider that the future safety cases supporting BWRX-300 developments should provide fuel crud estimates to underpin these assertions.

86. As discussed above, I consider that the BWRX-300 differs from existing BWRs in respect of the elongated chimney within the RPV and ICS system. BWRX-300 also depends solely on the CFD for clean-up, while I identified challenges in Step 1 related to availability across all modes. I therefore queried the impact of these in achieving effective chemistry control (ref. [71], RQ-01719 and RQ-01720 relate). The RP confirmed the expectation of increased core flow in BWRX-300 based on core flow calculations, which will provide effective mixing and therefore chemistry control. ONR fault analysis specialists have reviewed core flow calculations, with assessment not repeated here (ref. [72]). Chapter 23 of the PSR acknowledges that the ICS system may experience stagnant conditions during standby periods. The RP asserts that operating temperatures and material selection mitigate degradation in the ICS, with supporting crack growth rate analysis. Chapter 23 of the PSR also presents a review of reactor water chemistry control across all modes. This includes utilisation of the shutdown cooling system and over boarding to liquid waste management systems. Justification for the absence of ion exchange capacity in CUW system is based on higher CFD ion exchange capacity in comparison with existing BWRs, and a reduction in radwaste and worker doses. I judge this meets the expectations of ECH. 1 and 3 for a GDA Step 2.

87. During Step 1 of the GDA, I observed that there is currently no automated CIPS in the reference design for BWRX-300. A CIPS is present in UK ABWR however as a measure to reduce risks ALARP. Chapter 23 of the PSR presents a forward action (PSR23-333) to review this position in future, with non-foreclosure of options at this stage (ref. [8]). Given there is no decision with respect to the ultimate heat sink currently, I judge this approach will meet the expectations of ECH.3.

88. Based on my review of RCS chemistry in the PSR and supporting submissions, I judge that the RPs submissions have met the expectations of SAPs ECH.1 – 3, EHT.4 and EHT.5 for the purposes of a Step 2 GDA. I consider the designers of the BWRX-300 should provide suitable and sufficient evidence to underpin fuel crud estimates, justification of chemistry control systems, and completion of forward actions as part of the ongoing routine development of the BWRX-300 design and safety case.

4.3.2. Passive Safety Systems

89. SAP EKP.1 expects that the underpinning safety aim for any nuclear facility should be an inherently safe design. Relevant to chemistry, ECH.1 expects a systematic review to identify and analyse how chemistry can impact safety during normal operations and in fault and accident conditions. ECH.3 is also relevant, with expectation of suitable and sufficient systems for chemical control. It is clear therefore that an appropriate identification of chemistry risks and control will enable continued availability of passive safety systems.

90. To support the availability of passive safety systems, the RP presents three requirements (ref. [8]), as discussed in section 3 of this report. Relevant to the ICS pools, chapter 23 of the PSR identifies requirements for minimisation of corrosion of pipework and heat exchanger, respectively. For the PCCS, chapter 23 of the PSR identifies a requirement for minimisation of corrosion of PCCS pipework. I also note requirement for minimising corrosion of the containment closure head in contact with the reactor cavity pool.

91. The BWRX-300 design proposes demineralised water for the ICS pools (ref. [67]), with stainless steel lining, capacity for chemical dosing of biocides, and ion exchange for water clean-up (ref. [8]). Chemistry LCO are proposed for ICS pools, and presented in PSR Chapter 23 (ref. [8] and [71], RQ-02006 relates). I consider that application of pH control may present benefits to heat exchanger integrity and retention of radionuclides within ICS pools in the event of a heat exchanger leak (ref. [71], RQ-01730 relates). This currently relies on sampling to detect any activity in the event of a heat exchanger leak and subsequent isolation of the effected train. The RP confirmed however that additional design features may arise, with potential for pH control. I consider this relates to forward action PSR23-419. I discuss this in more detail in section 4.3.4 below. I judge this meets the expectations of the SAPs proportionately for a GDA Step 2. However, I consider that the BWRX-300 designers should demonstrate if other measures, such as pH control, are necessary to satisfy the expectations of EKP.1 and ECH.3, as part of ongoing routine development of the BWRX-300 design and safety case.

92. The RP proposes demineralised water in equipment pool and PCCS, with chemistry LCOs identified. These are presented in PSR Chapter 23 (ref. [8] and [71], RQ-02006 relates). I noted the potential stagnation of coolant within PCCS pipework due to infrequency of operation (ref. [71], RQ-01730 relates). The RP confirmed they expect continuous flow within PCCS pipework due to temperature differences between containment and equipment pools. Based on my review of submissions and RQ responses, I judge this meets the expectations of ECH.1.

93. Of further relevance to the PCCS, the equipment pool (which provides PCCS water) connects to the reactor cavity pool. This reactor cavity pool is in direct contact with the containment head. I consider this to be novel for BWRs, with UK ABWR possessing a “dry” containment head. The interconnecting SFP provides chemical control for both the equipment pool and reactor cavity pool. I judge this meets the expectations of ECH.1 for the purposes of a Step 2 GDA. However, given the duty associated with the SFP clean up system (SFP, equipment pool, and reactor cavity pool), I consider that the designers of the BWRX-300 should provide justification of the engineered chemistry control as part of ongoing routine design development.

94. Based on my sample, I judge the safety case meets expectations of EKP.1, ECH.1 and ECH.3 for passive safety systems for the purposes of a Step 2

GDA. However, I consider the BWRX-300 designers should provide evidence to underpin chemistry choices (specifically, pH control) and the chemistry clean-up capacity, as part of the ongoing routine design and safety case development.

4.3.3. Normal Operation Source Term

95. Source terms are the types, quantities and physical and chemical forms of the radionuclides present in a nuclear facility that have the potential to give rise to exposure to radiation, radioactive waste, or discharges to the environment. The derivation of the radioactive source term is a fundamental part of understanding and therefore being able to control the hazards associated with any nuclear facility. ONR expects that the RP is able to demonstrate and justify that this source term is appropriate to be used as the basis for the safety case in line with ECH.1 (ref. [13]) and NS-TAST-089 (ref. [58]).

96. As noted above in section 4.3.1, chapter 23 of the PSR presents the requirement that RCS chemistry will reduce the radioactive source term to minimise dose rates to workers and the public, radioactive waste accumulations and releases of radioactivity to the environment (ref. [8]).

97. The approach to define RCS circuit realistic normal operation source terms is based on the ANS ANSI/ANS-18.1-2020 standard (ref. [68]), while the design basis source term is prepared from the RP's fuel clad defect model. I note that ANS standards have been utilised in GDA of other LWRs including the AP1000 (ref. [73]), however the application of these standards required substantiation given differences in materials and chemistry. While I note that the OPEX used in the ANS standard is based on plants adhering to a reducing chemistry regime, I consider there are materialistic differences between BWRX-300 and US BWRs. I am content with the RP's assertion that this will generate a conservative source term for BWRX-300, given improvements regarding application of stainless steel in feedwater systems and cascaded heater drains. I also note positive comparison of the realistic and design basis source terms with the UK ABWR source terms to justify these for application in Step 2.

98. Chapter 23 of the PSR recognises the impact of chemistry in minimising source terms and importance of material selection (including replacement of carbon steels in feedwater systems with stainless steels and minimisation of cobalt to <0.05 % in general and <0.03 % in in-core components). However, it is unclear how the RP has considered optimisation of the use of stellite based material (ref. [71], RQ-01721 relates). The RP subsequently confirmed that it restricts use of high cobalt alloys such as stellite to those applications where no satisfactory alternative material is available. The RP achieves this across design teams through their As Low as Reasonably Achievable (ALARA) Design Criteria. I judge that the approach presented in chapter 23 of the PSR for stellite reduction appears reasonable and meets

the expectations of ECH.1 for the purposes of a Step 2 of GDA. However, I judge future safety cases supporting BWRX-300 developments should provide demonstration of stellite reduction.

99. The RP applies a factor of 2.5 from the realistic to design basis nitrogen-16 source term (ref. [8]). In comparison, UK ABWR applies a factor of 1.6 (ref. [47]). This appears to represent a conservatism in BWRX-300. This is captured by forward action PSR23-133 in ref. [8] (ref. [71], RQ-01996 relates) to optimise HWC. I consider this a positive development; however, I judge the BWRX-300 designers should provide additional evidence to substantiate the HWC range as part of the ongoing routine development of the BWRX-300 design and safety case development.

100. Based on my review of the chapter 23 of the PSR for normal operational source terms for BWRX-300, I judge the methodologies used in deriving source terms are reasonable and meet the expectations of ECH.1. I note forward action PSR23-133 in the PSR to develop end user source terms. Further, I judge that the source terms presented are conservative. I consider the RP should provide demonstration of stellite reduction as part of future normal business activities.

4.3.4. Accident Chemistry

101. In line with SAP ECH.1 the safety case should, by applying a systematic process, address all chemistry effects important to safety (ref. [13]). NS-TAST-GD-089 further explains that the scope of chemistry assessment is broader than just considering normal operations (ref. [58]). Many approaches to accident analyses can make assumptions and/or specific claims on the relative importance of chemical phenomena in justifying acceptable levels of safety. These assumptions and/or claims should be appropriately justified in the safety case. My assessment in this area focused on the RP’s demonstration that the risks associated with the three main accident topics (fission product chemistry, combustible gas chemistry, and core melt and in-vessel retention) will be appropriately modelled and adequately included in the safety case.

102. The categories of fault scenarios are principally identified in PSR Chapter 15 (ref. [29]). However, the design features and requirements relevant to accident chemistry are also presented in appendix C of PSR Chapter 23 (ref. [8]). Chapter 23 of the PSR identifies six accident chemistry requirements. These include minimisation of activity release (dry and wet scrubbing), hydrogen management (in and ex-vessel), and criticality control in the event of control rod injection failure.

103. Information relating to the BWRX-300 accident chemistry strategy is presented in response to RQ-01729 (ref. [71]). This describes the approach to identify chemistry claims or assumptions to minimise the accident consequences, and models used to inform the safety case assessment with

respect to accident chemistry. On the basis of my sample of the accident chemistry requirements presented in chapter 23 of the PSR, I judge that the expectations of ECH.1 are met for the purpose of a GDA step 2. I consider that the BWRX-300 accident chemistry topic is developing satisfactorily, and that there are no fundamental gaps in the strategy. The analysis approaches identified in chapter 23 of the PSR for the various accident scenarios are likely to be reasonable from a chemistry perspective, subject to completion of self-identified forward actions (see below).

104. I note that the RP has not completed development of a full Fault Schedule with the outputs of a comprehensive suite of fault analysis, with outputs therefore not available during GDA step 2 timescales. This has been followed up by an ONR Fault Studies inspector and is captured by the RP in forward actions, including: development of the fault schedule (PSR15.5-28); completeness of the fault list (15.5-30); defining and assessing severe accidents (PSR15-4) (ref. [72]). Therefore, the accident chemistry requirements identified in chapter 23 of the PSR do not consider a full set of requirements/dependencies placed on chemistry from fault analysis. Chapter 23 of the PSR identifies a forward action to identify further accident chemistry mitigation measures and associated requirements (PSR23-419). While not exhaustive, this includes pH buffering of water volumes, passive autocatalytic recombiners, and filtered containment venting. Given that the RP has self-identified and captured a forward action to identify further accident chemistry requirements, I am content that this meets the expectations of ECH.1.

105. Relevant to accident chemistry, the design reference includes a BIS. This delivers negative reactivity by injection of enriched sodium pentaborate decahydrate solution via ICS C return line. I consider this system to be equivalent to the standby liquid control (SLC) system in UK ABWR (ref. [60]). I judge application of enriched boron enables use of lower chemical concentration, positively reducing risk of crystallisation and ensuring system functionality. I note however that the BIS includes a single pump, in comparison to two in the SLC of UK ABWR. ONR fault analysis inspectors assessment relates, with assessment not repeated here (ref. [72]). Based on my review of the BIS and associated chemistry requirements however, I judge that the design and safety case meet the expectations of ECH.1 proportionately for a Step 2 GDA.

106. In summary, based on my assessment sample, I judge the accident chemistry aspects of the BWRX-300 design as presented in chapter 23 of the PSR is developing adequately for a fundamental step 2 GDA. However, I note there are related forward actions that the BWRX-300 designers will need to be completed as the generic BWRX-300 design, and associated safety case evidence, develops. These include forward action PSR23-419, to identify further accident chemistry mitigation measures and associated requirements as the full fault schedule and severe accident assessment is developed.

4.3.5. Reduction of risks ALARP

107. The most appropriate chemistry regime will be a holistic balance between all the safety aims as expected by ECH.2. This SAP expects an ALARP demonstration, proportionate to the level of risk and hazard, where there are chemistry options available. Related, SC.5 expects identification of optimism, uncertainty, and conservatism (ref. [13]). NS-TAST-GD-005 provides further guidance on expectations of an ALARP demonstration (ref. [55]).

108. PSR Chapter 23 presents a claim (2.4) that safety risks are reduced to ALARP (ref. [8]). Sub-claims of consideration of RGP and OPEX across all disciplines (claim 2.4.1 and 2.4.2 respectively) underpin this. Sub-claims are in turn supported by arguments (2.4.1 a – e and 2.4.2 a) related to maintaining material integrity and minimising dose and waste.

109. Based on my review of the PSR (ref. [8] and [9]), I judge that the scope and structure of the safety case is appropriate for the purpose of a Step 2 GDA. I note IAEA guidance does not explicitly include a chemistry chapter in the PSR (ref. [65]). I therefore welcome production of PSR Chapter 23. This is aligned with the key expectations of a chemistry safety case discussed in ONR TAGs, with application of a claims, argument and evidence approach (ref. [55], [56] and [57]). As detailed throughout my assessment, there are a number of chemistry requirements in PSR Chapter 23 (ref. [8]). I judge these to represent chemistry claims, in line with interpretation in NS-TAST-GD-089 (ref. [58]). While not a fundamental issue for Step 2, I judge that future safety cases supporting BWRX-300 developments should provide a consistent use of terminology for chemistry claims in the PSR.

110. I note specific claims regarding alignment with RGP and consider that the safety case is cognizant of RGP relevant to chemistry. I note that the BWRX-300 chemistry regime is in alignment with UK ABWR, with application of UK ABWR source terms to support justification in BWRX-300. I judge that where gaps remain with RGP (such as inclusion of a CIPS), the RP has appropriately captured these within forward actions.

111. The RP has begun to define LCOs throughout presented in PSR Chapter 23 (ref. [8] and [71], RQ-02006 relates), with control and diagnostic parameters identified. Based on my review of these and supporting submissions, I judge an adequate suite of LCOs is developing for BWRX-300 in line with the expectations of ECH.1. I consider however additional LCOs are yet to be determined in relation to radiochemistry. I note a forward action PSR23-420 in this regard in PSR Chapter 23 however, and I am content on this basis.

Based on my assessment, I judge that the BWRX-300 designers present an appropriate case to demonstrate risks have been reduced ALARP for the BWRX-300 design, in line with the expectations of ONR TAGs (ref. [55], [56] and [57]). I judge the safety case aligns with ONR expectations for scope and RGP, proportionately for a Step 2 GDA. While not a fundamental issue for Step 2, I judge that future safety cases supporting BWRX-300 developments should provide a consistent use of terminology for chemistry claims in the PSR.

5. Conclusions

112. This report presents the Step 2 chemistry assessment for the GDA of the BWRX-300 design. The focus of my assessment in this step was towards the fundamental adequacy of the design and safety case. I have assessed the SSSE chapters and relevant supporting documentation provided by the RP to form my judgements. I targeted my assessment, in accordance with my assessment plan (ref. [17]), at the content of most relevance to chemistry against the expectations of ONR's SAPs (ref. [13]), TAGs (ref. [14]) and other guidance which ONR regards as RGP, such as IAEA standards (ref. [59]).

113. Based upon my assessment, I have concluded the following:

- In relation to RCS chemistry, I judge this is aligned with the UK ABWR and represents RGP based on previous ONR assessment. I judge improvements to feedwater system material selection and heater drains design will enable lower feedwater corrosion products. I consider that as part of the ongoing development of the BWRX-300 design and safety case, the designers of the BWRX-300 should substantiate the chemistry control systems.

- I have not identified any fundamental shortfalls related to chemistry in the ICS or PCCS. I judge that the designers of the BWRX-300 should provide additional evidence to justify chemistry selection for the ICS pools and equipment pool clean up capacity in future safety cases and as part of ongoing routine design development.

- I am satisfied with the methodology applied in deriving the BWRX-300 source term and comparison with UK ABWR. I consider the designers of the BWRX-300 should provide additional justification to demonstrate stellite reduction SFAIRP as part of ongoing routine design development.

- I judge that an adequate accident chemistry strategy for the BWRX-300 design has been developed, with requirements identified across the main topics of relevance to accident chemistry. I consider that as part of the ongoing routine development of the BWRX-300 design and safety case, the designers of the BWRX-300 should implement the accident chemistry strategy and substantiate accident chemistry mitigation measures.

- Where I have identified gaps with RGP or requirements for further work over the course of my assessment, I am satisfied these have been appropriately captured with forward actions that the designers of the

BWRX-300 should progress. This includes provision of a CIPS and implementation of the accident chemistry strategy.

- The scope, structure and content of the safety case meets my expectations for two step GDA from a chemistry perspective. I judge however that future safety cases supporting BWRX-300 developments should provide a consistent use of terminology for chemistry claims in the PSR.

114. Overall, based on my assessment, and subject to the provision and assessment of suitable and sufficient supporting evidence in either a future Step 3 GDA or during site specific activities, I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design.

6. References

[1] GE-Hitachi, NEDO-34162, BWRX-300 UK GDA Safety, Security, Safeguards Environment Summary, Revision C, 15 July 2025, ONRW-2019369590-22495.

[2] GE-Hitachi, NEDO-34163, BWRX-300 UK GDA Chapter 1 – Introduction, Revision B, 11 July 2025, ONRW-2019369590-22413.

[3] GE-Hitachi, NEDO-34167, BWRX-300 UK GDA Chapter 5 - Reactor Coolant System and Associated Systems, Revision B, 11 July 2025, ONRW-2019369590-22393.

[4] GE-Hitachi, NEDO-34168, BWRX-300 UK GDA Chapter 6 - Engineered Safety Features, Revision B, 11 July 2025, ONRW-2019369590-22395.

[5] GE-Hitachi, NEDO-34173, BWRX-300 UK GDA Chapter 10 - Steam and Power Conversion Systems, Revision B, 11 July 2025, ONRW-2019369590-22417.

[6] GE-Hitachi, NEDO-34175, BWRX-300 UK GDA Chapter 12 - Radiation Protection, Revision B, 3 July 2025, ONRW-2019369590-22203.

[7] GE-Hitachi, NEDO-34194, BWRX-300 UK GDA Chapter 22 - Structural Integrity of Metallic System Structures and Components, Revision B, 3 July 2025, ONRW-2019369590-22202.

[8] GE-Hitachi, NEDO-34195, BWRX-300 UK GDA Chapter 23 - Reactor Chemistry, Revision C, 11 July 2025, ONRW-2019369590-22419.

[9] GE-Hitachi, NEDO-34199, BWRX-300 UK GDA Chapter 27 - ALARP Evaluation, Rev B, 11 July 2025, ONRW-2019369590-22420.

[10] GE-Hitachi, NEDC-34154P, BWRX-300 UK GDA Design Reference Report, Revision 3, April 2025, ONRW-2019369590-20194.

[11] ONR, NS-TAST-GD-096 - Guidance on Mechanics of Assessment - Issue 1.2, December 2022, https://www.onr.org.uk/publications/regulatory-guidance/regulatory-assessment-and-permissioning/technical-assessment-guides-tags/nuclear-safety-tags.

[12] ONR, ONR-RD-POL-002, Risk-informed and targeted engagements (RITE), Issue 2, May 2024, 2024/16720.

[13] ONR, Safety Assessment Principles for Nuclear Facilities (SAPs), 2014 Edition, Revision 1, January 2020, www.onr.org.uk/saps/saps2014.pdf.

[14] ONR, Technical Assessment Guides, https://www.onr.org.uk/publications/regulatory-guidance/regulatory-assessment-and-permissioning/technical-assessment-guides-tags.

[15] ONR, NS-TAST-GD-108 - Guidance on the Production of Reports for Permissioning and Assessment - Issue 2, December 2023, 2022/71935.

[16] ONR, ONR-GDA-GD-006 - New Nuclear Power Plants: Generic Design Assessment Guidance to Requesting Parties, Revision 1, August 2024. www.onr.org.uk/new-reactors/onr-gda-gd-006.pdf.

[17] ONR, BWRX-300 GDA – Step 2 Assessment Plan – Chemistry – Issue 1, August 2024, ONRW-2126615823-3870.

[18] ONR, Generic Design Assessment of the BWRX-300 - Step 2 Summary Report - Revision 1, December 2025, ONRW-2019369590-21328.

[19] GE-Hitachi, NEDO-34164, BWRX-300 UK GDA Chapter 2 - Site Characteristics, Revision B , 15 July 2025, ONRW-2019369590-22496.

[20] GE-Hitachi, NEDO-34165, BWRX-300 UK GDA Chapter 3 - Safety Objectives and Design Rules for Structures, Systems and Components, Revision C , 15 July 2025, ONRW-2019369590-22497.

[21] GE-Hitachi, NEDC-34166P, BWRX-300 UK GDA Chapter 4 - Reactor, Revision C, 11 July 2025, ONRW-2019369590-22500.

[22] GE-Hitachi, NEDO-34169, BWRX-300 UK GDA Chapter 7 - Instrumentation and Control, Revision B, 15 July 2025, ONRW-2019369590-22414.

[23] GE-Hitachi, NEDO-34170, BWRX-300 UK GDA Chapter 8 - Electrical Power, Revision C, 15 July 2025, ONRW-2019369590-22501.

[24] GE-Hitachi, NEDO-34171, BWRX-300 UK GDA Chapter 9A - Auxiliary Systems, Revision B, 11 July 2025, ONRW-2019369590-22415.

[25] GE-Hitachi, NEDO-34172, BWRX-300 UK GDA Chapter 9B - Civil Structures, Revision B, 15 July 2025, ONRW-2019369590-22416.

[26] GE-Hitachi, NEDO-34174, BWRX-300 UK GDA Chapter 11 - Management of Radioactive Waste, Revision B, 3 July 2025, ONRW-2019369590-22201.

[27] GE-Hitachi, NEDO-34176, BWRX-300 UK GDA Chapter 13 - Conduct of Operations, Revision B, 15 July 2025, ONRW-2019369590-22502.

[28] GE-Hitachi, NEDO-34177, BWRX-300 UK GDA Chapter 14 - Plant Construction and Commissioning, Revision B, 15 July 2025, ONRW-2019369590-22503.

[29] GE-Hitachi, NEDO-34178, BWRX-300 UK GDA Chapter 15 - Safety Analysis (Including Fault Studies, PSA and Hazard Assessment), Revision B, 11 July 2025, ONRW-2019369590-22392.

[30] GE-Hitachi, NEDO-34179, BWRX-300 UK GDA Chapter 15.1 - General Consideration, Revision B, 11 July 2025, ONRW-2019369590-22391.

[31] GE-Hitachi, NEDO-34180, BWRX-300 UK GDA Chapter 15.2 - Safety Analysis Identification, Categorisation, and Grouping of Postulated Initiating Events and Accident Scenarios, Revision B, 15 July 2025, ONRW-2019369590-22505.

[32] GE-Hitachi, NEDO-34181, BWRX-300 UK GDA Chapter 15.3 - Safety Analysis - Safety Objectives and Acceptance Criteria, Revision C, 15 July 2025, ONRW-2019369590-22506.

[33] GE-Hitachi, NEDO-34182, BWRX-300 UK GDA Chapter 15.4 - Safety Analysis Human Actions, Revision B, 15 July 2025, ONRW-2019369590-22507.

[34] GE-Hitachi, NEDO-34183, BWRX-300 UK GDA Chapter 15.5 - Deterministic Safety Analyses, Revision B, 15 July 2025, ONRW-2019369590-22509.

[35] GE-Hitachi, NEDO-34184, BWRX-300 UK GDA Chapter 15.6 - Probabilistic Safety Assessment, Revision B, 15 July 2025, ONRW-2019369590-22508.

[36] GE-Hitachi, NEDO-34185, BWRX-300 UK GDA Chapter 15.7 - Deterministic Safety Analyses - Analysis of Internal Hazards, Revision B, 15 July 2025 , ONRW-2019369590-22510.

[37] GE-Hitachi, NEDO-34186, BWRX-300 UK GDA Chapter 15.8 - Deterministic Safety Analyses - Analysis of External Hazards, Revision B, 15 July 2025, ONRW-2019369590-22511.

[38] GE-Hitachi, NEDO-34187, BWRX-300 UK GDA Chapter 15.9 - Summary of Results of the Safety Analyses, Revision B, 15 July 2025, ONRW-2019369590-22512.

[39] GE-Hitachi, NEDO-34188, BWRX-300 UK GDA Chapter 16 - Operational Limits and Conditions, Revision B, 15 July 2025, ONRW-2019369590-22513.

[40] GE-Hitachi, NEDO-34189, BWRX-300 UK GDA Chapter 17 - Management for Safety and Quality Assurance, Revision B, 15 July 2025, ONRW-2019369590-22514.

[41] GE-Hitachi, NEDO-34190, BWRX-300 UK GDA Chapter 18 - Human Factors Engineering, Revision B, 15 July 2025, ONRW-2019369590-22515.

[42] GE-Hitachi, NEDO-34191, BWRX-300 UK GDA Chapter 19 - Emergency Preparedness and Response, Revision B, 15 July 2025, ONRW-2019369590-22516.

[43] GE-Hitachi, NEDO-34192, BWRX-300 UK GDA Chapter 20 - Environmental Aspects, Revision B, 11 July 2025, ONRW-2019369590-22394.

[44] GE-Hitachi, NEDO-34193, BWRX-300 UK GDA Chapter 21 - Decommissioning and End of Life Aspects, Revision B, 11 July 2025, ONRW-2019369590-22418.

[45] GE-Hitachi, NEDO-34196, BWRX-300 UK GDA Chapter 24 - Conventional Safety and Fire Safety Summary Report, Revision B, 3 July 2025, ONRW-2019369590-22204.

[46] GE-Hitachi, NEDO-34197, BWRX-300 UK GDA Chapter 25 - Security, Revision B, 3 July, ONRW-2019369590-22205.

[47] GE-Hitachi, NEDO-34198, BWRX-300 UK GDA Chapter 26 - Interim Storage of Spent Fuel, Revision B, 11 July 2025, ONRW-2019369590-22401.

[48] GE-Hitachi, NEDO-34200, BWRX-300 UK GDA Chapter 28 - Safeguards, Revision B, 3 July 2025, ONRW-2019369590-22206.

[49] GE-Hitachi, NEDC-34148P, Scope of Generic Design Assessment, Revision 2, October 2024, ONRW-2019369590-13525.

[50] GE-Hitachi, NEDO-34087, BWRX-300 UK Generic Design Assessment Master Document Submission List, Revision 19, November 2025, ONRW-2019369590-25137.

[51] IAEA, Safety Standards, www.iaea.org.

[52] IAEA, Nuclear Security series, www.iaea.org.

[53] WENRA, Safety Reference Levels for Existing Reactors 2020, February 2021, www.wenra.eu.

[54] WENRA, Safety Objectives for New Nuclear Power Plants and WENRA Report on Safety of new NPP designs, September 2020, www.wenra.eu.

[55] ONR, NS-TAST-GD-005 - Regulating duties to reduce risks ALARP - Revision 12, September 2024, https://www.onr.org.uk/publications/regulatory-

guidance/regulatory-assessment-and-permissioning/technical-assessment-guides-tags/nuclear-safety-tags.

[56] ONR, NS-TAST-GD-051 - The purpose, scope and content of safety cases - Revision 7.1, December 2022, https://www.onr.org.uk/publications/regulatory-guidance/regulatory-assessment-and-permissioning/technical-assessment-guides-tags/nuclear-safety-tags.

[57] ONR, NS-TAST-GD-088 - Chemistry of Operating Civil Nuclear Reactor - Issue 3.1, January 2024, https://www.onr.org.uk/publications/regulatory-guidance/regulatory-assessment-and-permissioning/technical-assessment-guides-tags/nuclear-safety-tags.

[58] ONR, NS-TAST-GD-089 - Chemistry Assessment - Revision 1.1, December 2022, https://www.onr.org.uk/publications/regulatory-guidance/regulatory-assessment-and-permissioning/technical-assessment-guides-tags/nuclear-safety-tags.

[59] IAEA, Specific Safety Guide SSG-13, Chemistry Programme for Water Cooled Nuclear Power Plants, 2024, www.iaea.org/resources/safety-standards.

[60] ONR, Generic Design Assessment, Assessment of Reactors, UK Advanced Boiling Water Reactor, https://www.onr.org.uk/generic-design-assessment/assessment-of-reactors/uk-advanced-boiling-water-reactor-uk-abwr/.

[61] GE-Hitachi, 006N5064 - BWRX-300 Safety Strategy, Revision 6, January 2024, 2024/10561.

[62] GE-Hitachi, NEDC-34145P, BWRX-300 UK GDA Conventional Safety Strategy (Methods), Revision 1, August 2024, ONRW-2019369590-13984.

[63] GE-Hitachi, NEDC-34142P, BWRX-300 UK GDA Security Design Assessment Strategy, Revision 0, May 2024, ONRW-2019369590-9733.

[64] GE-Hitachi, NEDC-34140P, BWRX-300 UK GDA Safety Case Development Strategy, Revision 0, June 2024, ONRW-2019369590-10299.

[65] IAEA, Specific Safety Guide SSG-61, Format and Content of the Safety Analsyis Report for Nuclear Power Plants, September 2021, www.iaea.org.

[66] GE-Hitachi, 008N4658 - BWRX-300 Primary Water Chemistry Guidelines, Rev 0, July 2024, 2025/8856.

[67] GE-Hitachi, 006N6766 - BWRX-300 Water Quality: Technical Requirements Specifications, Revision 4, March 2024, 2025/8854.

[68] American National Standards Institute, ANSI/ANS-18.1-2020, Radioactive Source Term For Normal Operation Of Light Water Reactors, 2020, https://www.ans.org/.

[69] GE-Hitachi, DBR-0060223 - BWRX-300 Operating Water Chemistry Regime - Revision 1, September 2022, 2025/8853.

[70] ONR, Delivery Strategy for the Generic Design Assessment of the BWRX-300, Issue 1, 17 July 2024, ONRW-2019369590-11067.

[71] GE-Hitachi, NEDC-34288P, BWRX-300 UK GDA RQ, RO, RI Tracker, Rev.5, June 2025, ONRW-2019369590-22147.

[72] ONR, AR-01348 – BWRX-300 GDA – Step 2 Assessment Report – Fault Studies and Severe Accidents – Issue 1, July 2025, ONRW-2126615823-7711.

[73] ONR, ONR-GDA-AR-11-008 - Step 4 Reactor Chemistry Assessment of the Westinghouse AP1000® Reactor - Revision 0, November 2011, https://onr.org.uk/media/kukddfwj/ap1000-rc-onr-gda-ar-11-008-r-rev-0.pdf.

Appendix 1 – Relevant SAPs considered during the assessment.

SAP reference	SAP title
ECH.1	Engineering principles: chemistry – Safety cases
ECH.2	Engineering principles: chemistry – Resolution of conflicting chemical effects
ECH.3	Engineering principles: chemistry – Control of chemistry
ECH.4	Engineering principles: chemistry – Monitoring, sampling, and analysis
EHT.4	Engineering principles: heat transport systems – Failure of heat transport system
EHT.5	Engineering principles: heat transport systems – Minimisation of radiological doses
SC.5	The regulatory assessment of safety cases – Optimism, uncertainty, and conservatism
EKP.1	Inherent Safety