Office for Nuclear Regulation

Civil Nuclear Reactor Build - Generic Design Assessment

Step 2 Assessment of the Radiological Protection Aspects of Hitachi GE's UK Advanced Boiling Water Reactor (UK ABWR)

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EXECUTIVE SUMMARY

This report presents the results of my assessment of the radiological protection aspects of Hitachi GE Nuclear Energy, Ltd (Hitachi-GE) UK Advanced Boiling Water Reactor (UK ABWR) undertaken as part of Step 2 of the Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA).

The GDA process calls for a step-wise assessment of the Requesting Party's (RP) safety submission with the assessments getting increasingly detailed as the project progresses. ONR's Step 2 is an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including review of key nuclear safety and nuclear security claims with the aim of identifying any fundamental safety or security shortfalls that could prevent the issue of a Design Acceptance Confirmation (DAC). Therefore during Step 2 my work has focused on the assessment of the key claims in the area of radiological protection to judge whether they are complete and reasonable in the light of our current understanding of reactor technology.

In accordance with my Step 2 assessment plan I have interpreted claims for radiological protection as specific statements to demonstrate that the design has been optimised to ensure that:

- the quantities of radioactive material generated, especially where these have the ability to contribute to radiation exposure of operators, other workers or other persons on site, from all sources, and members of the public from direct radiation, have been minimised.
- doses received by operators, other workers or other persons on site from all sources, and members of the public from direct radiation are ALARP.

The standards I have used to judge the adequacy of the claims in the area of radiological protection have been primarily ONR's Safety Assessment Principles (SAPs) and Technical Assessment Guides (TAGs). In particular, I have used those SAPs dealing with fundamental principles, radiological protection, key engineering principles and numerical targets, and the TAGs on Demonstration of ALARP, Radiation Shielding, Fundamental Principles and Radiological Analyses (during operation and fault conditions). I have also used the Ionising Radiations Regulations 1999 (IRR99) and associated Approved Code of Practice (ACOP) and guidance.

My assessment work has involved regular engagement with the RP in the form of technical exchange workshops and progress meetings. In addition, my understanding of the ABWR technology, and, therefore, my assessment, has significantly benefited from visits to Japan Steel Works, Hitachi Works, Rinkai Works, and from being able to see and interact with the 3-Dimensional computer model of the ABWR reference plant at Hitachi Works.

My assessment has been based on the RP's Preliminary Safety Report (PSR) and its references relevant to radiological protection. The preliminary safety case aspects related to radiological protection is summarised in PSR reports on:

- "Definition of Radioactive Sources" which defines at a high level the source terms for UK ABWR in normal operations, during outage and during transport and storage of radioactive items, contaminated items and spent fuel.
- "Strategy to ensure that exposure is ALARP" which describes at a high level how aspects of the design and the approach to proposed operation of the facility have been optimised to ensure that doses to operators, other workers, or other persons on site from all sources, and members of the public from direct radiation, are ALARP.

The above reports represent an acceptable basis from which to develop a broader and more detailed radiological protection chapter within the Pre-Construction Safety Report (PCSR) which will be supported by a range of associated documents such as Topic Reports.

My assessment has identified the following areas of strength:

- The ABWR is a mature design and appears to incorporate a number of improvements which, on the basis of the evidence available at this stage, aim to reduce radiation doses to workers and members of the public through measures including:
    - Careful materials choices, mainly through the reduction of cobalt (and similar elements susceptible to neutron activation) present in the reactor coolant circuit);
    - The choice of reactor chemistry regime (the chosen chemistry regime is claimed to minimise the amount of radioactivity within the reactor coolant circuit).
- In addition there appears to be a body of operational experience which the RP is intending to use to support the Safety Case. If this information can be obtained it should form a useful body of evidence, with appropriate provenance, to assist the RP to make suitable arguments to strengthen the UK ABWR safety case.

During Step 2 I have identified the following areas that require follow-up:

- Further clarification of the source terms to be used as the basis of the UK ABWR safety case (this overlaps with a number of other specialist areas and will involve close ongoing interaction with other technical areas in GDA).
- Further development of an understanding of how the chosen chemistry regime will impact upon radiological protection.
- Further exploration of the approach taken to radiological zoning and the way it informs and defines the hierarchy of control measures.
- Further discussions over the approach taken to the design of radiation shielding.
- Further consideration of the radiological protection matters associated with the management of maintenance activities (including outages) and further exploration of radiological aspects specifically related to the boiling water reactor technology.
- Additional consideration of the design of the Heating, Ventilation and Air Conditioning (HVAC) system and its role in radiological protection.
- Further development of an understanding of how the arguments around, and supporting the demonstration of ALARP within the safety case are made.
- Clarification on how links to radiological protection within other topic areas e.g. interim spent fuel storage, are covered.
- A better understanding of the doses likely to be incurred during decommissioning and an assessment of how they have been reduced ALARP by optimisation of the “design for decommissioning”.
- Further exploration of the how the contributions made to doses to workers and members of the public resulting from direct radiation from the reactor building, the turbine-hall and the interim storage of spent fuel have been assessed.

Through my interactions with their Subject Matter Experts (SME) in radiological protection, I have found the RP to be very professional, open and straightforward in discussions and responsive to any queries I have raised.

The reports submitted to date by the RP addressing radiological protection aspects for the UK ABWR and assessed by ONR during step 2 represent an acceptable basis from which the RP will be able to develop a broader and more detailed radiological protection chapter within the PCSR, which will be supported by a range of associated documents such as specific topic reports. Therefore, ONR see no reason, on radiological protection grounds, why the UK ABWR should not proceed to step 3.

LIST OF ABBREVIATIONS

ABWR	Advanced Boiling Water Reactor
ACOP	Approved Code of Practice
ALARP	As Low As Reasonably Practicable
BMS	Business Management System
BSL	Basic Safety Level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
CST	Condensate Storage Tank
DAC	Design Acceptance Confirmation
DBA	Design Basis Accidents
EA	Environment Agency
FMCRD	Fine Motion Control Rod Drive
GDA	Generic Design Assessment
GEP	Generic Environmental Permit
Hitachi-GE	Hitachi-GE Nuclear Energy, Ltd
HVAC	Heating Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IRR99	Ionising Radiations Regulations 1999
ILW	Intermediate Level Waste
ISFS	Interim Spent Fuel Storage
JPO	(Regulators') Joint Programme Office
MHSWR99	Management of Health and Safety at Work Regulations 1999, as amended
NPP	Nuclear Power Plant
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PPE	Personal Protective Equipment

LIST OF ABBREVIATIONS

PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
REPPIR	Radiation (Emergency Preparedness and Public Information) Regulations 2001
RHR	Residual Heat Removal
RO	Regulatory Observation
RP	Requesting Party
RQ	Regulatory Query
SAP(s)	Safety Assessment Principle(s)
SCC	Stress Corrosion Cracking
SME	Subject Matter Expert
TAG	Technical Assessment Guide(s)
TSC	Technical Support Contractor
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1.1 Background

1. The Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA) process calls for a step-wise assessment of the Requesting Party's (RP) safety submission with the assessments getting increasingly detailed as the project progresses. Hitachi-GE Nuclear Energy, Ltd. (Hitachi-GE) is the RP for the GDA of the UK Advanced Boiling Water Reactor (UK ABWR).

2. During Step 1 of GDA, which is the preparatory part of the design assessment process, the RP established its project management and technical teams and made arrangements for the GDA of its ABWR design. Also, during Step 1 the RP prepared submissions to be evaluated by ONR and the Environment Agency (EA) during Step 2.

3. Step 2 of GDA is an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including review of key nuclear safety and nuclear security with the aim of identifying any fundamental safety or security shortfalls that could prevent the issue of a Design Acceptance Confirmation (DAC).

4. This report presents the results of my assessment of the radiological protection aspects of UK ABWR as presented in the UK ABWR Preliminary Safety Reports (PSR) (Refs 1 & 2) and supporting documentation on prospective dose modelling (Ref. 3).

1.2 Methodology

5. My assessment has been undertaken in accordance with the requirements of ONR's How2 Business Management System (BMS) procedure PI/FWD (Ref. 4). ONR's Safety Assessment Principles (SAPs) (Ref. 5), together with supporting Technical Assessment Guides (TAG) (Ref. 6) have been used as the basis for this assessment.

6. My assessment has followed my Step 2 Assessment Plan for radiological protection (Ref. 7) prepared in December 2013 and shared with the RP to maximise openness and the efficiency of our subsequent interactions.

2 ASSESSMENT STRATEGY

7. This section presents my strategy for the Step 2 assessment of the radiological protection aspects of the UK ABWR (Ref. 7). It also includes the scope of the assessment and the standards and criteria that I have applied.

2.1 Scope of the Step 2 Radiological Protection Assessment

8. The objective of my assessment for the UK ABWR was to review and judge whether the claims made by the RP related to radiological protection that underpin the safety aspects of the design are complete and reasonable in the light of our current understanding of reactor technology.

9. For radiological protection "safety claim" is interpreted as being:

- Specific statements to demonstrate that the design has been optimised to ensure that:
    - the quantities of radioactive material generated, especially where this has the ability to contribute to radiation exposure of operators / other workers / other persons on site from all sources and members of the public from direct radiation, have been minimised; and
    - doses received by operators / other workers / other persons on site from all sources and members of the public from direct radiation are As Low As Reasonably Practicable (ALARP).
- Any radiological protection related functional requirement which must be met to ensure that the plant is operated within its design basis*.
- Any requirement or constraint placed on the operating condition of the plant relating to radiological protection which must be met in order to allow the plant to be operated safely*.

* these areas have not been considered as part of my Step 2 assessment report, as the decisions to include the topic at Step 2 was not made until late into Step 1, therefore these areas will be considered as part of my Step 3 and 4 assessment.

10. During Step 2 I have also evaluated whether the safety claims related to radiological protection (as shown above with associated caveats) are supported by a body of technical documentation sufficient to allow me to proceed beyond Step 2.

11. Finally, during Step 2 I have undertaken the following preparatory work for my Step 3 assessment:

- improved ONR's knowledge of the design including use of the 3-Dimensional computer model of the ABWR reference plant at Hitachi Works to inform the plant layout and the radiological protection analyses;
- undertaken preparatory work and initial assessment, on a sampling basis, of the RP's radiological protection analyses and supporting arguments;
- held ongoing discussions about the development of arguments and how this will be achieved;
- Instigated high level recognition and consideration of how the framework for developing supporting evidence for Step 4 may be assembled and allowing this to inform the direction of travel;

- raised Regulatory Queries (RQs) in order to clearly articulate regulatory expectations in the area of radiological protection and the wider safety-case in general;
- working closely with the RP's Subject Matter Experts (SMEs) to provide guidance on the regulatory framework in the UK, and the importance of being able to clearly demonstrate ALARP, both in the outcome of the design, but also in the process to arrive at the design;
- liaised with colleagues looking at areas of common interest, where these present a challenge to radiological protection - e.g. the material choices associated with the Residual Heat Removal (RHR) system, material selection to minimise cobalt content in the primary circuit and the choice of reactor chemistry;
- decided on the scope and plan for the Step 3 assessment, including consideration of potential Technical Support Contractors (TSCs) and set-up the process to put required contracts in place for Step 3; and
- identified any significant design or safety case changes that may be needed, and communicated these to the RP.

2.2 Standards and Criteria

12. The goal of ONR's Step 2 assessment is to reach an independent and informed judgment on the adequacy of the RP's case for nuclear safety and security. For this purpose ONR's assessment is undertaken in line with the requirements of the How2 Business Management System (BMS) document PI/FWD (Ref. 4). Appendix 1 of Ref. 4 sets down the process of assessment; Appendix 2 explains the process associated with sampling of safety case documentation.

13. In addition, the SAPs (Ref. 5) constitute the regulatory principles against which duty holders' safety cases are judged, and, therefore, they are the basis for ONR's nuclear safety assessment and have been used for this Step 2 assessment. The SAPs 2006 Edition (Revision 1 January 2008) were benchmarked against the International Atomic Energy Agency (IAEA) standards (as they existed in 2004). They are currently being reviewed.

14. Furthermore, ONR is a member of the Western European Regulator's Nuclear Association (WENRA). WENRA has developed Reference Levels, which represent good practices for existing nuclear power plants, and Safety Objectives for new reactors (Ref. 9).

15. The relevant SAPs, IAEA standards and WENRA reference levels are embodied and enlarged on in the TAGs on radiological protection (Ref. 6). These guides provide an important tool for assessing the radiological protection aspects of the UK ABWR.

2.2.1 Safety Assessment Principles

16. The key SAPs (Ref. 5) applied within the assessment are:

- SAPs addressing Fundamental Principles FP.3 (Optimisation of protection), FP.4 (Safety assessment), FP.5 (Limitation of risks to individuals), FP.6 (Prevention of accidents), FP.7 (Emergency preparedness and response), FP.8 (Protection of present and future generations);
- Radiation Protection SAPs RP.1 (Normal operation), RP.2 (Accident conditions), RP.3 (Designated areas), RP.4 (Contaminated areas), RP.5 (Decontamination), RP.6 (Shielding);
- SAPs' Numerical Target NT.1 targets 1 (Normal operation – any person on the site), 2 (Normal Operation – any group on the site) and 3 (Normal operation – any person off the site) and NT.2 (Time at risk);

- Key Engineering Principles EKP.1 (Inherent safety), EKP.2 (Fault tolerance), EKP.3 (Defence in depth), EKP.4 (Safety function), EKP.5 (Safety measures).

2.2.2 Technical Assessment Guides

17. The following ONR TAGs have been used as part of this assessment (Ref. 6):

- NS-TAST-GD-005 (Rev 6) – ONR Guidance on the demonstration of ALARP;
- NS-TAST-GD-002 (Rev 4) – Radiation shielding;
- NS-TAST-GD-004 (Rev 4) – Fundamental principles;
- NS-TAST-GD-038 (Rev 4) – Radiological protection;
- NS-TAST-GD-043 (Rev 2) – Radiological analysis normal operation; and
- NS-TAST-GD-045 (Rev 2) – Radiological analysis fault conditions.

2.2.3 National and International Standards and Guidance

18. The following national and international standards and guidance are also relevant for this assessment:

- Relevant IAEA standards (Ref. 8):
  - Fundamental Safety Principles, Safety Fundamentals. International Atomic Energy Agency (IAEA) Safety Standards Series No. SF-1. IAEA, Vienna, 2006.
  - Safety of Nuclear Power Plants: Design. Specific Safety Requirements. International Atomic Energy Agency (IAEA). Safety Standards Series No. SSR-2/1. IAEA. Vienna. 2012.
  - Radiation Protection Aspects of Design for Nuclear Power Plants. IAEA Safety Standards Series, Safety Guide No. NS-G-1.13, International Atomic Energy Agency (IAEA) Vienna, 2005.

- WENRA references (Ref. 9):
  - Reactor Safety Reference Levels (January 2008)
  - Statement on Safety Objectives for New Nuclear Power Plants (NPP) (November 2010).
  - Report Safety of New NPP Designs (March 2013).

- Other national standards:
  - The Nuclear Installations Act 1965, as amended (NIA65). (Ref.10)
  - The Ionising Radiations Regulations (IRR99) and Approved Code of Practice (ACOP) and guidance (L121) (Ref. 11). These Regulations implement the European Basic Safety Standards Directive 96/29/Euratom, which in turn takes into account recommendations from the International Commission on Radiological Protection. I will be interested in forming a view as to how restriction of exposure, and in particular the requirement to follow the hierarchy of control measures, has been incorporated into the design of the UK ABWR. I will also be interested in how dose limitation, designation of controlled or supervised areas, and monitoring of designated areas will be defined and how duties of manufacturers under section 6 of the Health and Safety Work etc Act 1974 (Ref. 12) will be addressed by Hitachi-GE.
  - Additional legislation that will be used in my assessment includes the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) (Ref. 13) and the Management of Health and Safety at Work Regulations 1999, as amended (MHSWR99) (Ref 14).

2.3 Use of Technical Support Contractors

19. During Step 2 I have not engaged TSCs in support of my assessment, but I am currently drawing up a contract specification (in some cases with colleagues where there are areas of common interest) as part of my planning for Step 3.

2.4 Integration with Other Assessment Topics

20. Early in GDA I recognised that during the project there would be a need to consult with other assessors (including Environment Agency's assessors) as part of my assessment of the radiological protection aspects of the UK ABWR. Similarly, other assessors would require input from my assessment. These interactions are very important to ensure the prevention of assessment gaps and duplications, and are key to the success of the project. Thus, from the start of the project I made every effort to identify potential interactions between the radiological protection and other technical areas, with the understanding that this position would evolve throughout GDA.

21. Also, interactions between radiological protection and some technical areas need to be formalised since aspects of the assessment in those areas constitute formal inputs to the radiological protection assessment, and vice versa. These are:

- Civil engineering.
- External hazards.
- Probabilistic Safety Analysis (PSA), in particular Level 3 PSA.
- Fault-studies / Design Basis Analysis (DBA).
- Severe Accident Analysis.
- Control and instrumentation.
- Electrical and power supply systems.
- Reactor chemistry.
- Mechanical engineering.
- Structural integrity.
- Human factors.
- Management of safety and quality assurance.
- Radioactive waste management, spent fuel management and decommissioning.

22. Of the above interactions, only the civil engineering, structural integrity, reactor chemistry and radioactive waste and decommissioning interactions commenced formally during Step 2:

- Work to assess issues related to concrete specification (which has an impact on radiation shielding) is being led by civil engineering, with my input, as appropriate.

- The basis of the decision on materials choice for areas of plant where Stress Corrosion Cracking (SCC) needs to be to mitigated can have consequences for radiological protection. These areas will be considered once the decisions have been made by the RP and the assessment will be carried out jointly.

- Work is being done by reactor chemistry inspectors in the area of source-terms (which forms the main basis of the shielding / contamination control design) and is being focused by a Regulatory Observation (RO) and associated resolution plan.

- Work is also being done by the radioactive waste management and decommissioning inspector to understand the basis of the interim spent fuel storage solution, which will have radiological protection consequences for workers and for members of the public from direct radiation. We plan to work jointly on this part of the submission.

23. In addition to the above, there have been interactions between radiological protection fault studies and PSA, but mainly to co-ordinate the approach to Step 3.

24. There have been interactions with all other disciplines and although these interactions, which are expected to continue thorough GDA, are mostly of an informal nature, they are essential to ensure consistency across the technical assessment areas.

3 REQUESTING PARTY'S SAFETY CASE

25. This section presents a summary of the RP's preliminary safety case in the area of radiological protection. It also identifies the documents submitted by the RP which have formed the basis of my Step 2 assessment.

3.1 Summary of the RP's Preliminary Safety Case in the Area of Radiological Protection

26. The aspects covered by the UK ABWR preliminary safety case in the area of radiological protection can be grouped under the following 3 headings which are developed in the Basis of Assessment for the RP's Documentation:

- Definition of radioactive sources.
- Strategy to ensure that exposure is ALARP.
- Doses to members of the public from direct radiation from the site.

3.2 Basis of Assessment: RP's Documentation

27. The RP's documentation that has formed the basis for my assessment is:

- PSR report 1 – "Definition of Radioactive Sources". This document describes the sources of ionising radiation that are expected to exist in the UK ABWR. It furthermore provides detail of the type and quantities of radioactive materials that are generated (Ref. 1).
- PSR report 2 "Strategy to ensure that exposure is ALARP". This document details the approach taken to the design of UK ABWR to ensure that doses to workers and members of the public are ALARP. At this stage of development, it does not include doses from accidents (Ref. 2).
- GDA Prospective Dose Modelling as part of the submission of the Generic Environmental Permit (GEP) for the EA which carries out prospective dose modelling to members of the public resulting from direct radiation from the site. A range of exposure scenarios is considered (Ref. 3).
- Responses to Regulatory Queries (RQ) I have raised: RQ-ABWR-0158 (approach to shielding design), RQ-ABWR-0165 (approach to radiological zoning), RQ-ABWR-0174 (Interim Spent Fuel Storage (ISFS)) and RQ-ABWR-0166 (Pre-construction Safety Report (PCSR) glossary) (Ref 16).
- Responses to RQs raised by other technical areas: RQ-ABWR-0131 (concrete density) and RQ-ABWR-002 (minimisation of Stellites) (Ref 16).

28. In addition, in May 2014 the RP submitted to ONR for information an advance copy of the PCSR. Chapter 17 (Ref. 17) addresses radiological protection. Although I have not covered this report in my Step 2 formal assessment, seeing it has been useful to start planning and preparing my Step 3 work.

4 ONR ASSESSMENT

29. ONR How2 Business Management System. BMS: Permissioning – Purpose and Scope of Permissioning. PI/FWD – Issue 3. August 2011 (Ref. 4).

30. My Step 2 assessment has followed the strategy described in Section 2 of this report.

31. My assessment work has involved regular engagement with the RP's radiological protection SMEs. Three Technical Exchange Workshops (2 in Japan, 1 in the UK) and 8 progress meetings (mostly video conferences) have been held. I have also visited:

- Hitachi Rinkai Works, where reactor internal components and Fine Motion Control Rod Drive Units (FMCRD) are manufactured and tested, and where I gained an overview of their manufacturing capability. In addition I was able to see how the design of reactor recirculation pumps (amongst other things) had been improved to reduce radiation exposure to workers during maintenance.
- Japan Steel Works where they make large stainless steel components and I could see the fabrication techniques and sections of reactor pressure vessels for new reactor customers.

32. During my assessment, I have identified some shortfalls in documentation which have generally led to the issue of RQs; in total I have raised 4 RQs. Shortfalls in the safety case generally lead to the issue of ROs, however I have not so far raised any ROs.

33. Details of my assessment of the UK ABWR preliminary safety case, including the areas of strength that I have identified, as well as the items that require follow-up and the conclusions reached, are presented in the following sub-sections.

4.1 Definition of Radioactive Sources

4.1.1 Assessment

34. This report (Ref. 1.) outlines the sources of ionising radiation which need to be considered in order to design the shielding which is required to provide adequate protection of workers and members of the public. The report makes an estimate of the amount of activity to be found in the: reactor-core, reactor (cooling) water, reactor building (and associated systems e.g. spent-fuel pool), turbine building, and the liquid, gaseous and solid waste management and off-gas management systems. In addition there is a very high-level recognition that outages present a different source term (mainly Co-60) and that this accounts for the majority of the operational exposure. There is also a brief discussion on transport and storage of radioactive and / or contaminated items. A number of existing references are used of which at least one appears to be quite dated.

4.1.2 Strengths

35. The document provides a useful high-level introduction to this topic area, and provides a suitable framework for the development of a much more detailed submission.

4.1.3 Items that Require Follow-up

36. During my assessment I have identified the following additional potential shortcomings that I will follow-up during Step 3:

- The submission was provided while discussions associated with the response to the reactor chemistry source-terms RO are on-going. The source terms to be used as the basis of the UK ABWR safety case overlap with a number of other specialist areas and will involve close ongoing interaction with colleagues in reactor chemistry. Going forward there will need to be better alignment between sections of the safety case which discuss source terms: this will need to include a detailed assessment and narrative on how the chosen chemistry regime will impact upon radiological protection.

- There needs to be further consideration of the source terms associated with maintenance activities, particularly those in outages, and further, more detailed, exploration of issues related to boiling water reactor technology, specifically those that arise out of the direct-cycle design.

- There is only a limited reference in this submission to sources arising from interim spent fuel storage and a more detailed assessment of this will be required.

4.1.4 Conclusions

37. Based on my assessment of "definition of radioactive sources", I have concluded that the RP needs to do further work in this area to develop the submission, but that it is an acceptable report for Step 2.

4.2 Strategy to Ensure that Exposure is ALARP

4.2.1 Assessment

38. This report (Ref. 2) recognises that operators (and by implication designers) must demonstrate that exposure to workers is ALARP and that a hierarchy of control measures must be used focusing on engineering means (hence the importance of the design), with other means such as Personal Protective Equipment (PPE) only being used where engineering means are not possible or cost effective. It describes the principles to be adopted in UK ABWR as mainly those of minimising time spent in radiation areas by personnel, and minimising radiation levels by the use of shielding in areas of the plant that are routinely occupied. Further examples of more detailed design features e.g. flushing / draining points for decontamination are also described.

39. In addition the report describes the approach taken to radiation and contamination zoning. The zoning regime proposed in the PSR document did not align with the IRR99 ACOP. However I am aware that in response to an RQ, the arrangements now being proposed in the PSCR are different, and would appear to align with the ACOP. This approach to radiation and contamination zoning is intimately linked with the design of the shielding. Also presented are a range of buildings (e.g. turbine building) and components (e.g. reactor water clean-up system) within them, that have the potential to make the greatest contribution to personnel dose. The PSR report describes how these doses are controlled. Currently there is no consideration of doses under fault conditions or resulting from design-basis accident situations. The report refers out to other chapters to describe the impact on radiological protection resulting from the choice of reactor chemistry regime and materials choices. The report does not describe doses which may be incurred during decommissioning of the plant.

4.2.2 Strengths

40. The report recognises the requirement that exposure to workers must be ALARP and describes at a higher level the principles and processes used to ensure that this is reflected in the design.

41. It forms an adequate basis from which to proceed with the design optimisation, as part of the production of the PCSR.

4.2.3 Items that Require Follow-up

- Further development of an understanding of how the chosen chemistry regime will impact upon radiological protection.
- Further exploration of the approach taken to radiological zoning and the way it informs and defines the hierarchy of control measures and its alignment with the requirements of IRR99 and associated ACOP.
- Further discussions over the approach taken to the design of radiation shielding.
- Further consideration of the radiological protection matters associated with the management of maintenance activities (including outages) and further exploration of radiological aspects of boiling water reactor technology, specifically those that arise out of the direct-cycle design.
- Additional consideration of the design of the Heating, Ventilation and Air Conditioning (HVAC) system and its role in radiological protection.
- Further development of an understanding of how the arguments supporting the demonstration of ALARP within the safety case are made.
- Clarification on how links to radiological protection within other topic areas (e.g. ISFS are covered).
- A better understanding of the doses likely to be incurred during decommissioning and an assessment of how they have been reduced ALARP by optimisation of the "design for decommissioning".
- I am also aware that specific claims relating to radiological protection have been made in other parts of the RP's submission (which have not been considered as part of my Step 2 assessment as these are not described in the current radiological protection chapter or specifically referenced). For example the expected spread of contamination during normal operation (including outages) and under fault conditions is currently unclear in the overall submission. Clarity of this information is needed for radioactive waste assessment and for design features to aid decommissioning. I will follow this up during Step 3

4.2.4 Conclusions

42. Based on the outcome of my assessment of "strategy to ensure that exposure is ALARP", I have concluded that the RP needs to do further work in this area to develop the submission, but that it is an acceptable report for Step 2 of GDA.

4.3 Doses to Members of the Public from Direct Radiation from the Site

4.3.1 Assessment

43. The information for this part of the assessment is contained within section 9 "Prospective Dose Modelling" of the GEP submission to the EA (Ref. 3). The EA is responsible for the regulation of doses to the public resulting from discharges from the site under normal operation and expected events. ONR is responsible for regulation of doses to the public resulting from direct radiation from the site, although the EA do have an interest in total doses to the members of the public by virtue of EPR-2010 schedule 23 (Ref. 15). The key assessment criterion relevant to ONR is Target 3 "Normal operation - any person off the site" where the Basic Safety Objective (BSO) is 0.02mSv per calendar year, a value expected to be met by new reactors.

44. Essentially, the modelling is based on an idealised building representing the Turbine Building and using radiation transport code-modelling coupled with a number of exposure scenarios, including assumptions of occupancy and distance from the site boundary to generate a number of possible doses. Some of these scenarios generate doses to the public which exceed the BSO.

4.3.2 Strengths

45. I have reviewed at a high-level the approach taken to dose-modelling which appears to be reasonable on the basis of the information provided. The exposure scenarios seem relatively conservative.

4.3.3 Items that Require Follow-up

46. During my assessment of "Prospective Dose Modelling" I have identified the following potential shortcomings that I will follow-up during Step 3:

- Although conservative, some exposure scenarios presented prospective doses to the public resulting from direct radiation from the site that are above the BSO.
- It appears that only direct radiation from the turbine hall has been considered in the assessment (reactor building and radioactive waste building have not been modelled).
- The submission does not include an assessment of doses from direct radiation that will result from the ISFS facility, Intermediate Level Waste (ILW) storage facilities or the Condensate Storage Tank (CST).

4.3.4 Conclusions

47. Based on the outcome of my assessment of "Prospective Dose Modelling", I have concluded that the RP needs to do further work in this area to develop the submission, but that it is an acceptable report for Step 2.

4.4 Out of Scope Items

48. The following items have been left outside the scope of my Step 2 assessment of the UK ABWR radiological protection.

- Any radiological protection related functional requirement which must be met to ensure that the plant is operated within its design basis.
- Any requirement or constraint placed on the operating condition of the plant relating to radiological protection which must be met in order to allow the plant to be operated safely.

49. The reason for leaving these matters out of the scope of my Step 2 assessment is that they were not addressed as part of the RP submissions at Step 2.

50. The above omissions do not invalidate the conclusions from my Step 2 assessment. During my Step 3 assessment I will follow-up the above out-of-scope items as appropriate; I will capture this within my Step 3 Assessment Plan.

4.5 Comparison with Standards, Guidance and Relevant Good Practice

51. Section 2.2 above lists the standards and criteria I have used to judge the adequacy of the preliminary safety case. My overall conclusions in this regard can be summarised as follows:

- SAPs: There is recognition within the submissions of ONR's expectations as defined within the SAPs. In some areas, the safety case has been articulated in sufficient detail that I have confidence that ONR's expectations can be met adequately by the RP's submission for Step 3. However, in some areas there is limited awareness of ONR's expectations at this time and further work in some areas will be needed. Table 1 provides further details.
- TAGs: There is recognition within the submissions of ONR's expectations as defined within the TAGs. In some areas, the safety case has been articulated in sufficient detail that I have confidence that ONR's expectations can be met

adequately by the RP's submission for Step 3. However, in some areas there is limited awareness of ONR's expectations at this time and further work in some areas will be needed.

4.6 Interactions with Other Regulators

52. I have reviewed section 9 of "Prospective Dose Modelling" of the GEP submission provided for the EA and discussed the contents of this report with EA colleagues with interests in this area. I have provided ONR's high level review of this stating that the approach taken appears reasonable, but noted that this is an area which will be followed as part of my Step 3 assessment.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

53. The RP has provided a PSR for the UK ABWR for assessment by ONR during Step 2 of GDA. To some extent, the PSR together with its supporting references present the radiological protection claims that underpin the safety of the design.

54. During Step 2 I conducted an assessment of the parts of the PSR and its references that are relevant to the area of radiological protection against the expectations of the SAPs and TAGs. From this assessment I conclude the following:

- The ABWR is a mature design and appears to incorporate a number of improvements which, on the basis of the evidence available at this stage, aim to reduce radiation doses to workers and members of the public through measures including:
  - careful materials choices, mainly through the reduction of cobalt (and similar elements susceptible to neutron activation) present in the primary circuit; and
  - the choice of reactor chemistry regime (the chosen chemistry regime appears to reduce the deposition of radioactive species in the reactor coolant circuit).
- There appears to be a body of operational experience which the RP is intending to use to support the Safety Case. If this information can be obtained it should form a useful body of evidence, with appropriate provenance, to assist the RP to make robust, evidence backed arguments to support the UK ABWR safety case.

55. There are a number of areas which I intend to follow up as part of the my Step 3 assessment, namely:

- Further clarification of the source terms to be used as the basis of the UK ABWR safety case (this overlaps with a number of other specialist areas and will involve close ongoing interaction with other technical areas in GDA).
- Further development of an understanding of how the chosen chemistry regime will impact upon radiological protection.
- Further exploration of the approach taken to radiological zoning and the way it informs and defines the hierarchy of control measures.
- Further discussions over the approach taken to the design of radiation shielding.
- Further consideration of the radiological protection matters associated with the management of maintenance activities (including outages) and further exploration of radiological aspects specifically related to the boiling water reactor technology.
- Additional consideration of the design of the HVAC system and its role in radiological protection.
- Further development of an understanding of how the arguments supporting the demonstration of ALARP within the safety case are made.
- Clarification on how links to radiological protection within other topic areas (e.g. ISFS) are covered.
- A better understanding of the doses likely to be incurred during decommissioning and an assessment of how they have been reduced ALARP by optimisation of the “design for decommissioning”.
- Further exploration of the how the contributions made to doses to workers and members of the public resulting from direct radiation from the reactor building, the turbine-hall, radioactive waste building, ILW storage building, the ISFS facility and the condensate storage tank have been assessed.

56. In relation to my interactions with their SMEs in radiological protection, I have found the RP to be very professional, open and straightforward in discussions and responsive to any queries I have raised.

57. The reports submitted to date by the RP addressing radiological protection aspects for the UK ABWR and assessed by ONR during step 2 represent an acceptable basis from which the RP will be able to develop a broader and more detailed radiological protection chapter within the PCSR, which will be supported by a range of associated documents such as specific topic reports. Therefore, ONR see no reason, on radiological protection grounds, why the UK ABWR should not proceed to step 3.

5.2 Recommendations

58. My recommendations are as follows.

- Recommendation 1: The UK ABWR should proceed to Step 3.
- Recommendation 2: All the items identified as needing to be followed up should be included in the Step 3 Radiological Protection Assessment Plan.
- Recommendation 3: All the relevant out-of-scope items identified in sub-section 4.4 of this report should be included in the Step 3 Radiological Protection Assessment Plan.

6 REFERENCES

1 UK ABWR Generic Design Assessment - Preliminary Safety Report on Radiation Protection

Section 1 Definition of Radioactive Sources (XE-GD-0150)

http://www.hitachi-hgne-uk-abwr.co.uk/downloads/s2c_ukabwr-ga91-9901-0039-00001_preliminary_safety_report_on_radiation_protection_section1_definition_of_radioactive_sources.pdf

2 UK ABWR Generic Design Assessment - Preliminary Safety Report on Radiation Protection

Section 2 Strategy to ensure that the exposure is ALARP (XE-GD-0151)

http://www.hitachi-hgne-uk-abwr.co.uk/downloads/s3c_ukabwr-ga91-9901-0040-00001_preliminary_safety_report_on_radiation_protection_section2_strategy_to_ensure_that_the_exposure_is_alarp.pdf

3 UK ABWR Generic Design Assessment - Prospective Dose Modeling (HE-GD-0005)

http://www.hitachi-hgne-uk-abwr.co.uk/downloads/e8b_ukabwr-ga91-9901-0026-00001_prospective_dose_modeling.pdf

4 *ONR How2 Business Management System. BMS: Permissioning – Purpose and Scope of Permissioning.* PI/FWD – Issue 3. August 2011 www.hse.gov.uk/nuclear/operational/assessment/index.htm.

5 *Safety Assessment Principles for Nuclear Facilities*. 2006 Edition Revision 1. HSE. January 2008. http://www.onr.org.uk/saps/saps2006.pdf

6 ONR Technical Assessment Guides http://www.onr.org.uk/operational/tech_asst_guides/index.htm.

7 ONR-GDA-AP-13-012 - ABWR GDA - ONR Step 2 Assessment Plan - Radiological Protection - November 2013 (TRIM:2014/227761)

8 Publications of IAEA

Fundamental Safety Principles, Safety Fundamentals. International Atomic Energy Agency (IAEA) Safety Standards Series No. SF-1. IAEA, Vienna, 2006.

Safety of Nuclear Power Plants: Design. Specific Safety Requirements. International Atomic Energy Agency (IAEA). Safety Standards Series No. SSR-2/1. IAEA. Vienna. 2012.

Radiation Protection Aspects of Design for Nuclear Power Plants. IAEA Safety Standards Series, Safety Guide No. NS-G-1.13, International Atomic Energy Agency (IAEA) Vienna, 2005

http://www.iaea.org.

9 *Western European Nuclear Regulators' Association.*

Reactor Safety Reference Levels WENRA January 2008, *WENRA Statement on Safety objectives for* new nuclear power plants WENRA November 2010, *Safety of new NPP designs* WENRA March 2013 http://www.wenra.org/

10 *The Nuclear Installations Act 1965 (as amended)* http://www.legislation.gov.uk/ukpga/1965/57

11 *The Ionising Radiations Regulations 1999*. S.I. 1999 No. 3232.

http://www.hse.gov.uk/pubns/books/l121.htm

12 *The Health and Safety at Work etc Act 1974*

http://www.hse.gov.uk/legislation/hswa.htm

13 *Radiation (Emergency Preparedness and Public Information) Regulations 2001.* S.I. 2001 No. 2975.

http://www.hse.gov.uk/radiation/ionising/reppir.htm

14 *The Management of Health and Safety at Work Regulations 1999*

http://www.legislation.gov.uk/uksi/1999/3242/contents/made

15 *The Environmental Permitting (England and Wales) Regulations 2010*

http://www.legislation.gov.uk/ukdsi/2010/9780111491423/contents

16 *Hitachi-GE UK ABWR - Schedule of Regulatory Queries raised during Step 2. ONR. TRIM Ref. 2014/271889.*

Hitachi-GE UK ABWR - Schedule of Regulatory Observations raised during Step 2. ONR. TRIM Ref. 2014/271901.

17 *Hitachi GE UK ABWR GDA Draft PCSR*

Table 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP	Title description	Interpretation	Comment
FP.3	Optimisation of protection	Protection must be optimized to provide the highest level of safety that is reasonably practicable	There is recognition of this in the submissions for radiological protection, but further work in this area will be needed.
FP.4	Safety assessment	The duty holder must demonstrate effective understanding of the hazards and their control for a nuclear site or facility through a comprehensive and systematic process of safety assessment.	There is recognition of this in the submissions for radiological protection, but further work in this area will be needed.
FP.5	Limitation of risk to individuals	Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm	There is recognition of this in the submissions for radiological protection, which includes consideration of collective dose as well as the constraint on individual doses.
FP.6	Prevention of accidents	All reasonably practicable steps must be taken to prevent and mitigate nuclear or radiation accidents	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed.
FP.7	Emergency preparedness and response	Arrangements must be made for emergency preparedness and response in case of nuclear or radiation incidents	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed.
FP.8	Protection of present and future generations	People, present and future, must be protected against radiation risks.	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed.
RP.1	Normal operation	Adequate protection against exposure to radiation and radioactive substances in normal operation should be provided in those parts of the facility to which access needs to be gained	There is recognition of this in the submissions for radiological protection which will form an adequate basis for development of the safety case.
RP.2	Accident conditions	Adequate protection against exposure to radiation and radioactive contamination in accident conditions, should they occur, should be provided in those parts of the facility to which access needs to be gained.	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed.

SAP	Title description	Interpretation	Comment
		This should include prevention or mitigation of accident consequences.	
RP.3	Designated areas	Where appropriate, designated areas should be further divided, with associated controls, to restrict exposure and prevent the spread of radioactive substances	There is a good recognition of this area in the submissions for radiological protection, however additional work will be needed, which will be developed into Step 3.
RP.4	Contaminated areas	Appropriate provisions for protecting persons entering and working in contaminated areas should be provided.	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed, which will be developed into Step 3.
RP.5	Decontamination	Suitable and sufficient decontamination provisions for the people, the facility, its plant and equipment should be provided.	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed, which will be developed into Step 3.
RP.6	Shielding	Where shielding has been identified as a means of restricting dose, it should be effective under all conditions.	There is a good recognition of this area in the submissions for radiological protection, however additional work will be needed, which will be developed into Step 3.
NT.1	Assessment against targets	A safety case should be assessed against numerical targets and legal limits for normal operation, design basis faults, and radiological accident risks to people on and off the site.	
Target 1	Normal operation – any person on the site / Target 1		There is a good recognition of this area in the submissions for radiological protection, however additional work will be needed, which will be developed into Step 3.

SAP	Title description	Interpretation	Comment
	The targets and a legal limit for effective dose in a calendar year for any person on the site from sources of ionising radiation are: Employees working with ionising radiation: Basic Safety Level - BSL(LL): 20 mSv Basic Safety Objective - BSO: 1 mSv Other employees on the site: Basic Safety Level - BSL: 2 mSv Basic Safety Objective - BSO: 0.1 mSv Note that there are other legal limits on doses for specific groups of people, tissues and parts of the body (IRR99). Note: LL means legal limit		
Target 2	Normal operation – any group on the site	Target 2 The targets for average effective dose in a calendar year to defined groups of employees working with ionising radiation are: Basic Safety Level - BSL: 10 mSv Basic Safety Objective - BSO: 0.5 mSv	There is a good recognition of this area in the submissions for radiological protection, however additional work will be needed in this area which will be developed into Step 3
Target 3	Normal operation – any person off the site	Target 3 The target and a legal limit for effective dose in a calendar year for any person off the site from sources of ionising radiation originating on the site are: Basic Safety Level - BSL(LL): 1 mSv Basic Safety Objective - BSO: 0.02 mSv	There is a good recognition of this area in the submissions for radiological protection, however information provided so far is incomplete and appears to suggest that the dose to any person off the site from normal operations for the UK ABWR could be above the BSO. Additional work will be needed in this area which will be developed into Step 3.

SAP	Title description	Interpretation	Comment
	Note that there are other legal limits to tissues and parts of the body (IRR). Note: LL means legal limit		
NT.2	Time at risk	There should be sufficient control of radiological hazards at all times.	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed
EKP.1	Inherent safety	The underpinning safety aim for any nuclear facility should be an inherently safe design, consistent with the operational purposes of the facility	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed
EKP.2	Fault tolerance	The sensitivity of the facility to potential faults should be minimised	There is no recognition of this in the submissions for radiological protection at this time and further work in this area will be needed
EKP.3	Defence in depth	A nuclear facility should be so designed and operated that defence in depth against potentially significant faults or failures is achieved by the provision of several levels of protection.	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed
EKP.4	Safety function	The safety function(s) to be delivered within the facility should be identified by a structured analysis.	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed
EKP.5	Safety measures	Safety measures should be identified to deliver the required safety function(s).	There is limited recognition of this in the submissions for radiological protection at this time and further work in this area will be needed