Office for Nuclear Regulation

New Reactor Division – Generic Design Assessment

Step 2 Assessment of the Radiological Protection of UK HPR1000 Reactor

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EXECUTIVE SUMMARY

This report presents the results of my Radiological Protection assessment of the UK HPR1000 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 increasing in detail as the project progresses. Step 2 of GDA is an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including ONR's review of key nuclear safety and nuclear security claims (or assertions). The aim is to identify any fundamental safety or security shortfalls that could prevent ONR from permitting the construction of a power station based on the design.

During GDA Step 2 my work has focused on the assessment of the Radiological Protection aspects within the UK HPR1000 Preliminary Safety Report (PSR), and a number of supporting references and supplementary documents submitted by the RP, focusing on design concepts and claims.

The standards I have used to judge the adequacy of the RP's submissions in the area of Radiological Protection have been primarily ONR's Safety Assessment Principles (SAPs), in particular SAPs Fundamental Principles (FP) 3, 4, 6 and 8 and Radiological Protection (RP) 1, 2, 3, 4, 5 and 7, Numerical Target (NT) 1, 2 and 3 and Key Engineering Principles (EKP) 1. I have also used ONR's Technical Assessment Guides (TAGs): NS-TAST-GD-005 (Rev 7) – ONR Guidance on the demonstration of ALARP, NS-TAST-GD-002 (Rev 5) – Radiation shielding, NS-TAST-GD-038 (Rev 6) – Radiological protection and NS-TAST-GD-043 (Rev 3) – Radiological analysis normal operation. I have also made use other relevant standards and guidance from the International Atomic Energy Agency (IAEA), the Western European Nuclear Regulators' Association (WENRA) and the Nuclear Energy Agency (NEA) which are included in the references.

My GDA Step 2 assessment work has involved regular engagement with the RP in the form of technical exchange workshops and progress meetings, including meetings with the plant designers.

The UK HPR1000 PSR is primarily based on the Reference Design, Fangchenggang Unit 3 (FCG3), which is currently under construction in China. Key aspects of the UK HPR1000 preliminary safety case claims related to Radiological Protection, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- That the Chinese regulations that the UK HPR1000 (FCG3) has been assessed against as well as UK guidelines and requirements for radiological protection are both derived from international recommendations.
- That ALARP (As Low As Reasonably Practicable) principles and the design considerations for ALARP will be implemented in the UK HPR1000 design.
- That the source terms associated with radiation protection have been adequately considered.
- That adequate radiation protection measures against exposure to radiation and radioactive substances will be provided during normal operation and fault or accident conditions.
- That a proposed dose optimisation process aiming at reducing the potential doses received by workers to ALARP levels will be considered in UK HPR1000 design.
- That the radiological risk fault and accident conditions will be adequately considered.

During my GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Radiological Protection I have identified the following among areas of strength:

- An awareness of UK legislative requirements is demonstrated, along with a more detailed understanding of requirements related to demonstrating relevant risks are reduced to levels that are ALARP.
- That the PSR provides high-level examples of how the facility layout and equipment are designed with ALARP considerations in mind and demonstrates the application of lessons learned from the operation of predecessor plants.
- That the RP's documentation provides a useful high level introduction to how the source terms will be defined. This gives an indication of which UK HPR1000 systems source terms will be developed for and how they will be derived. I consider that this provides a suitable basis to develop the UK HPR1000 specific source terms in future submissions.
- A radiation and contamination zoning system is described which will adopt a graded approach, in line with Relevant Good Practice (RGP).
- That the PSR considers optimisation of the collective dose based on operational experience (OPEX) feedback and RGP.

During my GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Radiological Protection I have identified the following among areas that require follow-up:

- A broader examination of the requirements of IRR17 (The Ionising Radiations Regulations 2017) (Ref. 7) needs to be carried out in Step 3 of GDA, looking at requirements that may affect the generic design.
- Further information is required to demonstrate how radioactivity within the reactor design has been reduced so far as is reasonably practicable (SFAIRP) through material choices, operating practices and chemistry control. As GDA progresses, I will expect the RP to provide suitable and sufficient evidence to demonstrate how operational practices and procedural controls which directly affect the source term have been adequately considered, to ensure radioactivity is reduced SFAIRP.
- The outlined approach to developing the FCG3 source terms does not include actinides in the main radionuclide groups, on the basis that actinide concentration will be negligible. The evidence underpinning this has yet to be provided and will be required in Step 3 of GDA.
- The RP has not yet defined source terms that can be shown to be applicable to the UK design. Development of the UK HPR1000 source term will be required in Step 3 of GDA, including definition of the assumptions used to adapt the FCG3 source term and further information on the RGP used to define and justify the source term.
- The RP's safety submissions should be developed to clearly demonstrate how the hierarchy of control measures has been applied to the design, with a focus on using engineering controls in the first instance.
- The RP ALARP methodology (Ref. 5) published so far is high-level and general. More detail will be required in Step 3 of GDA on the application of ALARP to occupational exposure.
- A collective dose target, and other dose metrics as appropriate, should be developed for the UK HPR1000 and it should be demonstrated that these are broadly comparable to leading operational Pressurised Water Reactors (PWRs) of a similar design.
- When the UK HPR1000 source term is fully developed and justified, the direct radiation dose estimate to the most exposed member of the public needs to be calculated using a more representative and precise methodology to ensure that direct radiation doses to the public are well characterised, reduced SFAIRP and can be compared with the relevant Basic Safety Objective (BSO).

During my GDA Step 2 assessment, I have not identified any fundamental safety shortfalls in the area of Radiological Protection that might prevent the issue of a Design Acceptance Confirmation (DAC) for the UK HPR1000 design.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
BSL	Basic Safety Level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
CPR	Chinese Pressurised Water Reactor
CGN	China General Nuclear Power Corporation
DAC	Design Acceptance Confirmation
DBA	Design Basis Accident
DEC	Design Extension Condition
EA	Environment Agency
EDF	Électricité de France
GB	Great Britain
GNI	General Nuclear International
GNS	Generic Nuclear System Ltd
IAEA	International Atomic Energy Agency
IRR17	The Ionising Radiations Regulations 2017
IRR99	The Ionising Radiations Regulations 1999
JPO	(Regulators') Joint Programme Office
NEA	Nuclear Energy Agency
NPP	Nuclear Power Plant
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PCER	Pre-construction Environmental Report
PRMS	Plant Radiation Monitoring System (KRT)
PSA	Probabilistic Safety Analysis
PSR	Preliminary Safety Report (includes security and environment)
PWR	Pressurised Water Reactor

RGP	Relevant Good Practice
RHWG	Reactor Harmonization Working Group (of WENRA)
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RQ	Regulatory Query
SAA	Severe Accident Analysis
SAP(s)	Safety Assessment Principle(s)
SFAIRP	So Far As Is Reasonably Practicable
SSC	Structures, Systems and Components
TAG	Technical Assessment Guide(s)
TSC	Technical Support Contractor
UK	United Kingdom
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

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 increasing in detail as the project progresses. General Nuclear System Ltd (GNS) has been established to act on behalf of the three joint requesting parties (China General Nuclear Power Corporation (CGN), Électricité de France (EDF) and General Nuclear International (GNI)) to implement the GDA of the UK HPR1000 reactor. For practical purposes GNS is referred to as the 'UK HPR1000 GDA Requesting Party' (RP).

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 the UK HPR1000 reactor. Also, during Step 1 the RP prepared submissions to be assessed by ONR and the Environment Agency (EA) during Step 2.

3. Step 2 commenced in November 2017. Step 2 of GDA is an overview of the acceptability, in accordance with the regulatory regime of Great Britain (GB), of the design fundamentals, including ONR's assessment of key nuclear safety and nuclear security claims (or assertions). The aim is to identify any fundamental safety or security shortfalls that could prevent ONR permitting the construction of a power station based on the design.

4. My assessment has followed my GDA Step 2 Assessment Plan for Radiological Protection (Ref. 1) prepared in October 2017 and shared with the RP to maximise openness and transparency.

5. This report presents the results of my Radiological Protection assessment of the UK HPR1000 as presented in the UK HPR1000 Preliminary Safety Report (PSR) Chapter 22 (Ref. 2), Chapter 26 (Ref. 6) and associated documentation (Refs. 3, 4 and 5).

2 ASSESSMENT STRATEGY

6. This section presents my strategy for the GDA Step 2 assessment of the Radiological Protection aspects of the UK HPR1000 (Ref. 1). It also includes the scope of the assessment and the standards and criteria I have applied.

2.1 Scope of the Step 2 Radiological Protection Assessment

7. The objective of my GDA Step 2 assessment was to assess relevant design concepts and claims made by the RP related to Radiological Protection. In particular, my assessment has focussed on a demonstration of the following:

- Doses to workers and direct radiation doses to members of the public are As Low As Reasonably Practicable (ALARP) under normal operating conditions.
- Radiation sources are well characterised and radioactivity within the design has been reduced so far as is reasonably practicable (SFAIRP).
- The UK HPR1000 design will comply with the requirements of the Ionising Radiations Regulations 2017 (IRR17) (Ref.7) in principle.

I had also intended to assess the following:

- That the ALARP principle has been applied to post accident access by mitigation staff.

However at the time of writing, although there are a number of claims related to worker doses during fault conditions, insufficient evidence has been provided at Step 2 to carry out a meaningful assessment of this. I will follow this up in Step 3.

8. Decommissioning is not specifically mentioned in PSR Chapter 22 (Ref. 2), having a separate PSR Chapter 24 (Ref. 18). There are a number of high level claims in Chapter 24 related to design for decommissioning and decommissioning planning and strategy. Chapter 24 and its associated documentation have been assessed by the Nuclear Liabilities Inspector and will not be discussed further here, however further detail on occupational exposure during the decommissioning phase will be required in Step 3.

9. Further information on the UK HPR1000 PSR scope including the range of normal operations is given in PSR Chapter 4 General Safety and Design Principles (Ref. 19).

10. The scope of the PSR in terms of civil structures is given in PSR Chapter 2 General Plant Description (Ref. 20). Detail on the scope of for the UK HPR1000 GDA is given in the GDA Scope Report (Ref. 22).

11. The Interim Spent Fuel Store is not included within PSR Chapter 2 (Ref. 20) but it is stated that high level information will be included on this in later GDA submissions. This is an acceptable position for the RP to take for Step 2; however I will follow this up in Step 3 to ensure that enough information is provided to enable the impact on off-site radiation doses due to direct radiation shine to be adequately considered.

12. It should be noted that the Ionising Radiations Regulations 1999 (IRR99) (Ref. 17) were in force when the PSR was issued (at the start of Step 2) with IRR17 (Ref. 7) coming into force from the 1st January 2018. Changes in the regulations were discussed with the RP with the impact of the change deemed minimal at Step 2.

13. During GDA Step 2 I have also evaluated whether the safety claims related to Radiological Protection are supported by a body of technical documentation sufficient to allow me to proceed with GDA work beyond Step 2.

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

- Increased familiarisation with the UK HPR1000 design to provide a basis for planning subsequent, more detailed, assessment during Steps 3 and 4 of GDA.
- Engaged with the RP via progress teleconferences and face-to-face technical meetings, workshops and plant visits.
- Reviewed a preliminary document schedule for Step 3.
- Undertaken a coarse review of an early version of Chapter 22 of the PCSR

2.2 Standards and Criteria

15. For ONR, the primary goal of the GDA Step 2 assessment is to reach an independent and informed judgment on the adequacy of a preliminary nuclear safety and security case for the reactor technology being assessed. Assessment was undertaken in accordance with the requirements of the Office for Nuclear Regulation (ONR) How2 Business Management System (BMS) guide NS-PER-GD-014 (Ref. 8).

16. In addition, the Safety Assessment Principles (SAPs) (Ref. 9) constitute the regulatory principles against which duty holders' and RPs' safety cases are judged. Consequently the SAPs are the basis for ONR's nuclear safety assessment and have therefore been used for the GDA Step 2 assessment of the UK HPR1000. The SAPs 2014 Edition are aligned with the International Atomic Energy Agency (IAEA) standards and guidance.

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

18. The relevant SAPs, IAEA standards and WENRA Reference Levels are embodied and expanded on in the Technical Assessment Guides (TAGs) relevant to Radiological Protection (Ref. 10). These guides provide the principal means for assessing the Radiological Protection aspects in practice.

2.2.1 Safety Assessment Principles

19. The key SAPs (Ref. 9) applied within my assessment are SAPs FP.3, FP.4, FP.6, FP.8, RP.1, RP.2, RP.3, RP.4, RP.5, RP.7 and EKP.1 (see also Table 1 for further details).

2.2.2 Technical Assessment Guides

20. The following Technical Assessment Guides have been used as part of this assessment (Ref. 10):

- NS-TAST-GD-002 (Rev 5) – Radiation Shielding
- NS-TAST-GD-038 (Rev 6) – Radiological Protection
- NS-TAST-GD-005 (Rev 7) – ONR Guidance on the Demonstration of ALARP
- NS-TAST-GD-043 (Rev 3) – Radiological Analysis Normal Operation

2.2.3 National and International Standards and Guidance

21. The following national and international standards and guidance have been considered as part of this assessment:

IAEA standards (Ref. 11)

- 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. 12)

- Western European Nuclear Regulators' Association. Reactor Harmonization Group. WENRA Safety Objectives for New Power Reactors. WENRA, December 2009.
- Western European Nuclear Regulators' Association. Reactor Harmonization Group. WENRA Statement on Safety Objectives for New Nuclear Power Plants November 2010.
- Western European Nuclear Regulators' Association. Reactor Harmonization Group. Report on Safety of new NPP designs March 2013.

The Ionising Radiations Regulations (IRR17) and Approved Code of Practice (ACOP) and guidance (L121) (Ref. 7)

Occupational Radiological Protection Principles and Criteria for designing New Nuclear Power Plants. Nuclear Energy Agency, Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA) 2010. (Ref. 13)

Information System on Occupational Exposure. (Ref. 14)

2.3 Use of Technical Support Contractors

22. During Step 2 I have not engaged Technical Support Contractors (TSCs) to support my assessment of Radiological Protection for the UK HPR1000:

2.4 Integration with Other Assessment Topics

23. Early in GDA, I recognised the importance of working closely with other inspectors (including Environment Agency's inspectors) as part of the Radiological Protection assessment process. Similarly, other inspectors sought input from my assessment of Radiological Protection for the UK HPR1000. I consider these interactions are key to the success of the project in order to prevent or mitigate any gaps, duplications or inconsistencies in ONR's assessment. From the start of the project, I have endeavoured to identify potential interactions between the Radiological Protection and other technical areas, with the understanding that this position will evolve throughout the UK HPR1000 GDA.

24. The key interactions I have identified are as follows. Note that this list is not exhaustive.

- Reactor Chemistry provides input to the Source Term aspects of the Radiological Protection assessment. This formal interaction has commenced during GDA Step 2. This work is being led by the Reactor Chemistry Inspector.
- Mechanical Engineering provides input to the Source Term aspects of the Radiological Protection assessment and ventilation design. This formal interaction has not commenced during GDA Step 2.

- Civil Engineering provides input to the Radiation Shielding aspects of the Radiological Protection assessment. This formal interaction has not commenced during GDA Step 2.
- Nuclear Liabilities provides input into the ALARP justification for waste, spent fuel and decommissioning strategies. This formal interaction has not commenced during GDA Step 2.
- The Radiological Protection assessment provides input to the public exposure from direct shine aspects of the Environment Agency's Environmental assessment. This formal interaction has commenced during GDA Step 2. This work is being led by Radiological Protection.
- Radiological protection provides input into the radiological consequences assessment of Fault Studies, PSA and SAA. This formal interaction has not commenced during GDA Step 2.

3 REQUESTING PARTY'S SAFETY CASE

25. During Step 2 of GDA the RP submitted a PSR (Ref. 2) and other references (Refs. 3, 4 and 5), which outline a preliminary nuclear safety case for the UK HPR1000. 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 Radiological Protection assessment of the UK HPR1000 during GDA Step 2.

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

26. The aspects covered by the UK HPR1000 PSR Chapter 22 (Ref. 2) in the area of Radiological Protection can be broadly grouped into the following headings:

- Radiation Protection Legislation: The PSR briefly describes the Chinese regulatory framework and compares it to the UK's.
- Application of ALARP: The PSR outlines the RP's understanding of the ALARP principle and optimisation. It claims that plant structures, systems and components (SSCs) will be designed to ensure that radiation exposures are ALARP, including operational considerations focussing on implementation of a robust radiation protection programme. The PSR description was augmented by the issue during Step 2 of the RP's ALARP Methodology (Ref. 5), which outlines aspects of their proposed ALARP decision making process.
- Definition of the Source Terms: A preliminary introduction to the approach used to estimate the source terms for the HPR1000 (FCG3 Reference Plant) is provided. This includes how the source terms will be used, definition of the main radionuclide groups, definition of the three types of source term and examples of source term assessment methodologies. Further detail on the source term is provided in the Normal Operation Source Term Strategy Report (Ref. 3) and the Report of Radionuclide Selection during Normal Operation (Ref. 4) which are the first documents provided of a suite of source term documentation to be provided for Step 3.
- Radiation Protection Measures: The PSR outlines some radiation protection measures for minimising exposure to ionising radiation. These are; classification and zoning of areas, shielding, ventilation, monitoring of radiation and contamination, certain operational considerations.
- Personal Dose Monitoring and Dose Assessment: The PSR considers dose monitoring and assessment. It states that the optimised dose assessment will be based on the UK HPR1000 Reference Plant (FCG3). The dose optimisation methodology is outlined and the RP claims that summation of the optimised collective dose data will allow a collective dose target for the UK HPR1000 design to be developed.

27. The initial assessment of off-site radiological dose to the public due to direct radiation shine is given in the UK HPR1000 PSR Chapter 26 – Environment (Ref. 6), which includes a simple calculation of off-site radiological dose.

3.2 Basis of Assessment: RP's Documentation

28. The RP's documentation that has formed the basis for my GDA Step 2 assessment is presented in PSR Chapter 22 (Ref. 2), PSR Chapter 26 (Ref. 6) and the following documentation:

- UK HPR1000 ALARP Methodology (Ref. 5).
- Normal Operation Source Term Strategy Report (Ref. 3).
- Report of Radionuclide Selection during Normal Operation (Ref. 4).

29. At the time of writing my assessment report, I had also raised three Regulatory Queries (RQs), to facilitate my assessment, as a result of gaps I identified in the documentation formally submitted to ONR. These were RQs: RQ-UKHPR1000-0024, RQ-UKHPR1000-0031 and RQ-UKHPR1000-0048 (Ref. 15). The RP's responses to these RQs have also formed part of the formal assessment I have undertaken during Step 2 of GDA.

30. During April 2018, the RP submitted to ONR an advance copy of the UK HPR1000 PCSR for information. Chapter 22 (Ref. 24) addresses Radiological Protection. Having early visibility of the scope and content of this chapter has been useful in the planning and preparation of my GDA Step 3 assessment work.

4 ONR ASSESSMENT

31. This assessment has been carried out in accordance with HOW2 guide NS-PER-GD-014, “Purpose and Scope of Permissioning” (Ref. 8).

32. My Step 2 assessment work has involved regular engagement with the RP’s radiological protection specialists, i.e.one Technical Exchange Workshop in China and four progress meetings plus additional informal contacts via telephone. I have also visited Ling Ao 3, a Chinese Pressurised Water Reactor (CPR-1000) (the predecessor of the HPR 1000 design) operated by CGN at their Daya Bay nuclear facility. This visit, which included access to designated radiation controlled areas, gave extremely useful insights into how IRR17 might be applied to a similar unit built in the UK.

33. During my GDA Step 2 assessment, as explained in Section 3, I identified some gaps in the documentation formally submitted to ONR. Consistent with ONR’s Guidance to Requesting Parties (Ref. 16), these normally lead to RQs being issued. At the time of writing my assessment report, in Radiological Protection, during Step 2, I had raised three RQs requesting further information from the RP, to facilitate my assessment.

34. Similarly, and again consistent with ONR’s Guidance to Requesting Parties (Ref. 16), more significant shortfalls against regulatory expectations in the generic safety case are captured by issuing Regulatory Observations (ROs). At the time of writing my assessment report in Radiological Protection, during Step 2, I had not raised any ROs.

35. Details of my GDA Step 2 assessment of the UK HPR1000 preliminary safety case in the area of Radiological Protection, including the conclusions I have reached, are presented in the following sub-sections of the report. This includes the areas of strength I have identified, as well as the items that require follow-up during subsequent Steps of the GDA of UK HPR1000.

4.1 Radiation Protection Legislation

4.1.1 Assessment

36. In order for the UK HPR1000 to successfully complete the GDA process, the RP must demonstrate that the design can, in principle, be operated in a way that is compliant with the requirements of relevant legislation. For radiological protection, the key legislation is IRR17 (Ref. 5).

37. Section 22.3 of the PSR (Ref. 2) briefly describes the GB legislative requirements and compares them to the Chinese requirements. It should be noted that when the PSR was written, IRR99 (Ref. 17) was still in force although this was superseded by IRR17 (Ref. 7) on January 1st 2018. The PSR commits to a review the design against the revised legislation in Step 3 of GDA, which is a prudent step.

38. Most of the comparisons drawn between Chinese and GB legislation in the PSR (Ref. 2) are qualitative, for example in stating that current Chinese and GB legislation is ultimately based on the same publication by the International Commission on Radiological Protection (ICRP60). IRR99 (Ref. 17) effective dose limits for employees (20mSv per year) and the public (1mSv per year) are quoted and it is stated that these limits will be met by the UK HPR 1000. The IRR99 eye lens dose equivalent limit of 150 mSv per year for employees is also quoted. In IRR17 (Ref. 7), the revised limit is 20mSv per year. The RP should confirm compliance with this revised lower limit as part of the review mentioned in the previous paragraph.

39. During my visit to the Ling Ao 3 Nuclear Power Plant (NPP) in China, I noted that access and egress, contamination control and monitoring arrangements are all very similar to the practices I would expect to see in the UK. This gives me confidence that

Chinese and GB legislative requirements drive towards many of the same outcomes and hence that the UK HPR1000 can be operated in a manner which is compliant with the requirements of IRR17 (Ref. 7).

40. The requirements of IRR17 (Ref. 7) to reduce doses SFAIRP are discussed in some detail and this feeds into the following section of the PCSR where commitments are made on ensuring radiation exposures are ALARP for the UK HPR1000 design.

4.1.2 Strengths

41. During my GDA Step 2 assessment of "Radiation Protection Legislation", I have identified the following area which I consider to be a strength:

- The RP's awareness of GB legislative requirements is demonstrated, along with a more detailed understanding of requirements related to reducing relevant risks to levels that are ALARP.

4.1.3 Items that Require Follow-up

42. During my GDA Step 2 assessment of "Radiation Protection Legislation" I have identified the following additional potential shortfalls that I will follow-up during Step 3 of GDA:

- A broader examination of the requirements of IRR17 (Ref. 7) needs to be carried out in Step 3 of GDA, looking at specific requirements that may affect the design, such as regulation 9 – Restriction of exposure, regulation 17 - Designation of controlled or supervised areas, regulation 19 – Additional requirements for designated areas and regulation 20 – Monitoring of designated areas. This will include any relevant changes from IRR99 (Ref. 17).

4.1.4 Conclusions

43. Based on the outcome of my assessment of "Radiation Protection Legislation", I have concluded that the RP has recognised the relevant requirements in the UK and that this assessment work, supported by my plant visit, have provided some initial confidence that the UK HPR 1000 is likely to be able to comply with IRR17 (Ref. 7). The RP will need to do further work in Step 3 of GDA to demonstrate this in detail.

4.2 ALARP Considerations

4.2.1 Assessment

44. This section focuses on the RP's overall ALARP strategy and ALARP design considerations specific to Radiological Protection, including how radioactivity in the UK HPR1000 primary coolant will be reduced SFAIRP. Specific radiological protection measures are discussed further in Section 4.4. Demonstration that occupational exposure has been reduced SFAIRP is a key requirement of IRR17 (Ref. 7) and hence a key part of my Radiological Protection assessment.

Reducing Radioactivity to ALARP

45. Chapter 22 of the PSR (Ref. 2) recognises that the doses from exposure to ionising radiation should be ALARP throughout the life of the UK HPR1000. A high-level description of their ALARP demonstration process and the principle of optimisation, are presented. The PSR states that an optimisation process is important in demonstrating ALARP below relevant Basic Safety Levels (BSLs) with the aim of meeting the relevant Basic Safety Objectives (BSOs) where reasonably practicable for a new facility. This description does not fully align with the description of BSLs and BSOs in the SAPs.

Operators have an overriding duty to consider whether risks have been reduced to levels that are ALARP irrespective of whether the BSOs are met. As such it is usually inappropriate to use the BSOs as design targets or to denote when "ALARP" has been achieved. Engagement with the RP on the topics of ALARP and numerical targets is on-going, to ensure ONR's expectations are well understood in these areas.

46. ONR's expectation is that the generation and transport of radioactivity within UK HPR1000 should be reduced SFAIRP. This assessment considers the key claims from Chapter 22 relevant to the demonstration of this.

47. The PSR claims that material selection for SSCs will be optimised to reduce radiation and contamination hazards SFAIRP. This is supported by the claim that materials will be selected with an absence or low content of isotopes susceptible to activation to form radiologically significant radionuclides, thereby ensuring that potential doses are ALARP. As an example it is stated that the FCG3 design reduces the amount of cobalt base hard-alloy and antimony-base alloys.

48. I therefore raised RQ-UKHPR1000-0048 (Ref. 15) to seek further information on the RP's proposed approach to material selection optimisation, in relation to its impact on the source term. This RQ focussed on cobalt base alloys and potential sources of antimony and silver in the UK HPR1000 design. The RP's response provides information on their general approach to controlling the cobalt content of various alloys, including the use of limits and further information on the use of cobalt alloys in some components, including their surface areas. The RP states that antimony-base alloys are not used in the primary circuit of the FCG3 design and that silver is only used in some seal gaskets. The absorber rods of the Rod Cluster Control Assemblies (RCCA) contain 80% silver but are physically separated from the primary coolant.

49. Based on the information provided so far, I am content that that the RP has a good understanding of the importance of material selection in reducing levels of radioactivity in the UK HPR1000 primary coolant. The RP has also given examples of such steps for the FCG3 design, which provides a further indication that the RP will be able to demonstrate that levels of radioactivity have been reduced SFAIRP in the UK HPR1000 design in the later stages of GDA.

50. Implementing appropriate chemistry control also has a significant impact on the behaviour (i.e. generation and transport) of radioactivity. This is discussed in more detail by the RP in a separate chapter of the PSR. As the generation and transport of radioactivity is affected by choices made in other technical areas, such as Reactor Chemistry, I expect there to be a clear link between these areas to demonstrate that radioactivity has been reduced SFAIRP, overall. As GDA progresses, further information will be required to demonstrate how operational practices and procedural controls may impact the generation and transport of radioactivity with the UK HPR1000. This is a significant multi-disciplinary part of my assessment and will require close working with several disciplines, including as a minimum, Reactor Chemistry and Mechanical Engineering.

UK HPR1000 ALARP Design Considerations

51. Design considerations for ALARP, as related to matters concerned with radiological protection, are discussed in PSR Chapter 22 (Ref. 2). For example, the RP claims facility layout design considerations in the UK HPR1000 design, such as the:

- Simplification of routine operational and maintenance tasks to reduce task duration and hence exposure of workers to ionising radiation;
- Provision of adequate shielding between sources of radiation and general access areas;
- Provision of an "active" workshop for maintenance of contaminated equipment.

52. The design of equipment is also specifically considered. For example, the RP claims the UK HPR1000 design features:

- The design of high reliability, durable components to reduce maintenance and repair required;
- Equipment which can be easily disassembled for maintenance or repair;
- Where practicable the use of remote techniques for operation, repair, monitoring and inspection of equipment.

53. I am content that this information, given in PSR Chapter 22 (Ref. 7), provides adequate evidence at Step 2 that the RP has considered the reduction of occupational exposure as part of the UK HPR1000 design process. This provides a good platform for developing the ALARP case for Radiological Protection in the later stages of GDA.

54. The RP's ALARP Methodology (Ref. 5) gives further detail of their proposed arrangements for making ALARP judgements, as GDA progresses. ONR's overall assessment of Ref. 5 has been co-ordinated by the Project Technical Inspector. ONR's overall, consolidated, Step 2 assessment position on the adequacy of Ref. 5 is therefore presented in the Summary Report (Ref. 21). My report presents my Step 2 assessment of Ref. 5, from a Radiological Protection perspective.

55. The important, positive aspects of Ref. 5, I have identified include the RP's recognition of the requirement to review the evolution of the UK HPR1000 design, undertake a comparison against relevant good practice (RGP) and worldwide operational experience (OPEX) feedback, and carry out further design improvements where they are judged to be demonstrably "ALARP".

4.2.2 Strengths

56. During my GDA Step 2 assessment of "ALARP Considerations", I have identified the following aspects which I consider to be strengths:

- The PSR (Ref. 2) recognises that a radiological dose optimisation process is required to ensure radiological doses to workers are ALARP. This includes capturing the requirement to undertake, where appropriate, optioneering and the use of feedback loops to assess the reasonable practicability of candidate options.
- The PSR (Ref. 2) provides high level examples of how the UK HPR1000 facility layout and equipment is designed with ALARP considerations in mind and demonstrates the application of lessons learned from the operation of predecessor plants such as the CPR1000.

4.2.3 Items that Require Follow-up

57. During my GDA Step 2 assessment of "ALARP Considerations" I have identified the following additional potential shortfalls that I will follow-up during Step 3 of GDA:

- Further information is required to demonstrate how, during normal operations, radioactivity within the UK HPR1000 primary coolant will be reduced SFAIRP through material choices, operating practices and reactor chemistry. In particular there is limited information available currently to demonstrate how operational practices and procedural controls which affect the source term have been considered to ensure radioactivity is reduced SFAIRP. In addition, there is currently no commitment in the PSR to minimise source terms SFAIRP except by material selection.
- Where the radiological source term is affected by choices made in other technical areas, there should be a clear evaluation of the effects on the radiological source term, and impact upon radiological protection, to

demonstrate that the generation and transport of radioactivity has been reduced SFAIRP, overall.

- The adequacy of the RP's application of their ALARP methodology to relevant scenarios to demonstrably justify occupational exposure to ionising radiation is reduced SFAIRP.

4.2.4 Conclusions

58. Based on the outcome of my assessment of "ALARP Considerations", I have concluded that the RP has provided an acceptable demonstration of their plans to address ALARP as GDA progresses. I am satisfied the information presented is fit-for-purpose for Step 2. The RP will need to do further work in Step 3 of GDA to develop their ALARP methodology for occupational radiation exposure and to demonstrate that radioactivity in UK HPR1000 primary coolant has been reduced SFAIRP.

4.3 Definition of the Source Term

4.3.1 Assessment

59. The source terms for the UK HPR1000 are not yet defined, but the PSR Chapter 22 (Ref. 2) provides a preliminary introduction to the approach the RP has used to estimate the source terms for FCG3. Two other documents have also been issued in Step 2 which give further information about the source term. These are the Normal Operation Source Term Strategy Report (Ref. 3) and the Report of Radionuclide Selection during Normal Operation (Ref. 4).

60. For normal operations, the RP will develop three "types" of source term: realistic, operation and design basis. Table 22.5-1 of the PSR Chapter 22 (Ref. 2), outlines how source terms are used for various purposes within the generic design and safety case, such as the: collective dose assessment to workers, design of shielding and zoning and building layouts.

61. The Normal Operation Source Term Strategy Report (Ref. 3) further develops the detail on seven source term categories that that have been defined by the RP, which are:

- Primary Coolant Source Term.
- Spent Fuel Assembly Source Term.
- Secondary Coolant Source Term.
- Derived Source Term (the concentration of each radionuclide present within 16 main SSCs).
- Gaseous and Liquid Discharges.
- Airborne Activity (airborne radioactivity concentrations of different buildings).
- Activated Structures Source Term (which includes decommissioning).

62. For each category, a brief scope is identified and a comprehensive document structure that will define the source terms is described. I am content that the RP's approach to source term categorisation provides a good framework to allow provision of the data necessary to support the Radiological Protection safety case in areas such as radiation shielding and zoning design, dose assessment and equipment qualification.

63. The PSR Chapter 22 (Ref. 2) highlights the main radionuclide groups within the primary coolant source term and typical radionuclide concentrations. Production estimates are provided for some radionuclides. These groups are fission products (typical radionuclide concentrations provided for noble gases, iodine, I-131 eq., Cs-134 and Cs-137), activated corrosion products (Co-58 and Co-60), tritium, C-14, N-16 and N-17.

64. The Report of Radionuclide Selection during Normal Operation (Ref. 4) gives the full list of the nuclides considered in each of the three groups defined for the UK HPR1000. This list has been based on theoretical analysis and the considerable OPEX available to the RP via CGN and EDF, which I consider represents RGP in terms of source term definition. The report lists 47 fission products, 6 activation products and 9 corrosion products of significance in the normal operation source term. I do not consider that there are obvious omissions from these lists from a radiological protection point of view. The full justification for inclusion or not of radionuclides will be explored in GDA Step 3.

65. The Report of Radionuclide Selection during Normal Operation (Ref. 4) states that actinide concentrations in the primary coolant are "negligible" due to very low fuel failure rates and so a list of significant actinides is not defined. Low levels of actinides, whilst providing insignificant levels of external radiation, can be a significant internal radiation hazard during normal operation and into decommissioning, due to their long half-lives. This being the case, I will need the RP to provide an extremely robust justification during GDA Step 3 of why no actinides are considered to present a significant hazard for normal operations.

4.3.2 Strengths

66. During my GDA Step 2 assessment of "Definition of the Radiological Source Terms", I have identified the following aspects which I consider to be strengths:

- The documentation provides a useful high-level introduction to how the radiological source terms will be defined for UK HPR1000. This gives an indication of what systems radiological source terms will be developed for and how they will be derived. This appears to provide a suitable basis to develop the UK HPR1000 specific radiological source terms as GDA progresses.
- Source terms are based on theoretical analysis and the considerable OPEX available to the RP via CGN and EDF, which I consider represents RGP in terms of source term definition

4.3.3 Items that Require Follow-up

67. During my GDA Step 2 assessment of "Definition of Source Term" I have identified the following potential shortfalls that I will follow-up during Step 3 of GDA:

- The outlined approach to developing the FCG3 source terms does not include actinides in the main radionuclide groups discussed, as it is claimed that actinide concentration will be negligible. I will need the RP to provide an extremely robust justification during GDA Step 3 of why no actinides are considered to present a significant hazard for normal operations.
- The RP has not yet defined source terms that can be shown to be directly applicable to the UK HPR1000 design. Development of the UK HPR1000 source term will be required in Step 3 of GDA, including definition of the assumptions used to adapt the FCG3 source terms and further information on the RGP used to define and justify the source terms.
- The UK HPR1000 radiological source terms definition and justification is important for a number of technical areas and is affected by some of the decisions made in these areas, such as reactor chemistry. The RP should demonstrate how the radiological source terms information is adequately integrated, controlled and used consistently across these areas, as GDA progresses.

4.3.4 Conclusions

68. Based on the outcome of my assessment of the "source term definition" I have concluded that significant further work is required in this area as source terms applicable to the UK HPR1000 design are still to be developed. The Step 2 submissions are however a suitable basis to develop these source terms and provide a high level description of the approach that will be used to define the source terms. I have therefore concluded that the information submitted is acceptable for Step 2 of the GDA process.

4.4 Radiation Protection Measures

4.4.1 Assessment

69. This section assesses some of the specific radiological protection measures identified in the PSR (Ref. 2) to ensure that radiation exposures are ALARP.

70. The PSR (Ref. 2) claims that operational considerations at the design stage are focussed on the implementation of a robust radiation protection programme to ensure that radiation exposures are ALARP. Key administrative controls highlighted in the PSR include prior risk assessment, procedures (including local rules), a system to investigate incidents and signage.

71. High level information is provided on radiological risk assessment under fault and accident conditions but will need to be developed further to consider doses under fault conditions and to demonstrate that the radiological risk is adequately controlled. As GDA progresses I will be working closely with the relevant disciplines to assess the UK HPR1000 design against the Numerical Targets defined in the SAPS (Ref. 9).

72. The PSR describes the approach to radiation zoning, which will serve as a basis for the UK HPR1000:

- overall layout;
- heating, ventilation and air conditioning (HVAC) system design;
- shielding design; and
- measures to prevent the spread of radioactive contamination.

73. My assessment of each of these is presented in the corresponding sub-section below.

Overall Layout

74. Regulation 17 of IRR17 (Ref. 7) requires the designation of controlled and supervised areas. SAP RP.3 (Ref. 9) states that where appropriate, designated areas should be further divided, with associated controls, to restrict exposure and prevent the spread of radioactive material. The approach outlined in the PSR designates controlled and supervised areas based on potential annual doses and effective dose rates. The PSR states that areas are zoned according to the different levels of expected external radiation, surface contamination and airborne contamination. I consider that this provides a good basis for compliance with the requirements of IRR17.

75. Controlled areas are further divided into four sub-zones indicated by colours (green, yellow, orange and red). The sub-zones are further divided again for the purposes of shielding design. Table 22.6-1, of the PSR (Ref. 2) outlines the upper and lower dose rate limits for each sub-zone. As GDA progresses, further detail will be required on how these limits have been derived, taking into account surface and airborne contamination, to ensure that radiological dose to workers from both external and internal sources is adequately controlled and ALARP.

76. The PSR discusses some requirements for controlled areas such as specific training, change rooms, body surface contamination monitors and decontamination and first aid facilities. Further detail will be required in Step 3 of GDA on controls for each of the sub-zones such as access / egress controls and the use of Personal Protective Equipment (PPE).

Measures to Prevent Radioactive Contamination

77. As highlighted in SAP RP.7 – Hierarchy of control measures (Ref. 9) and IRR17 (Ref. 7) there should be a hierarchy of control measures to optimise radiological protection, first and foremost focussing on engineered means, then supporting systems of work and lastly PPE. PSR Chapter 22 (Ref. 2) does not explicitly outline the application of this principle in the design; however a number of ALARP considerations in the design are outlined as described in paragraph 52.

78. SAPs paragraph 597 highlights that for high dose rate areas access should be controlled by physical means such as interlocks, alarms, or locked doors to prevent unauthorised entry. The PSR Chapter 22 (Ref. 2) states that there will be provision of adequate access controls between areas with different levels of external radiation, surface contamination and airborne contamination. The PSR also states that access to the red zone is usually forbidden and that they are separated from other areas by physical barriers such as walls and doors. The use of monitoring systems to provide data on the accessibility of plant areas is also proposed as well as the use of signage to avoid unnecessary exposure due to inadvertent entry.

79. I raised RQ-UKHPR1000-0024 (Ref. 15) on access control to avoid inadvertent radiation exposure. In the response to this RQ the RP provided an overview of how the concept of hierarchy of controls has been considered in the radiological protection design for FCG3. Examples of engineering controls are provided in the response such as a shield walls and locked doors to red zones; however it states that the key is controlled by an administrative process. Engineered features such as mechanical interlocks provide higher reliability than administrative controls which can be more easily defeated. The RQ response also explains that installed radiation and contamination monitors use alarms with local warning devices including lights and sirens to warn plant workers whilst signals are also routed to the control room. This is an adequate response for GDA Step 2. Further justification of the proposed approach will be required in Step 3 on how access is controlled to these areas, particularly in relation to the doors to these areas.

80. Various methods for monitoring radiation and radioactive contamination are described in the PSR (Ref. 2) for the purposes of preventing unnecessary exposure and monitoring radiation exposure of workers to ensure doses are ALARP. This includes installed and portable monitors. It is claimed that there will be a sufficient quantity available to cover periodic inspection and maintenance. Consideration is given to using installed equipment to monitor ambient dose rates, airborne activity and surface contamination (for monitoring people and articles). The Plant Radiation Monitoring System (PRMS) monitors barrier integrity and identifies abnormal changes in radioactivity on-site and in effluents to reduce radiation exposures to workers and the public. An overview is also provided for the process radioactivity monitoring sub-system, effluent monitoring and accident and post-accident monitoring. The information provided, together with my knowledge of the monitoring philosophy applied in the CGN plant Ling Ao 3, gives me confidence that ONR expectations with regards to monitoring for radiological protection can be met by the UK HPR1000 design.

Radiation Shielding Design

81. Adequate radiation shielding should form an integral part of the wider dose optimisation strategy. The PSR provides a high level description of the approach used

for shielding design including the required parameters and the methods used for FCG3. It discusses using shielding to restrict doses to both workers and the public and that it should be effective under normal operation and fault conditions. The RP will need to give detailed consideration of the engineering for shielding designs, particularly complex designs, that will be required when the UK HPR1000 radiological source terms and shielding design becomes more mature, as GDA progresses. Similarly, ONR's assessment of the adequacy of the UK HPR1000 shielding design will be undertaken in the later stages of GDA, as this work is finalised by the RP. Based on the information provided and interactions with the RP, I am content that the RP has a well-developed understanding of the shielding requirements of the UK HPR1000 and that the methods outlined in the PSR are appropriate.

82. SAP RP.6 (Ref. 9) requires consideration of localised levels of radiation due to streaming through locations where the radiation shielding is less effective. I therefore raised RQ-UKHPR1000-0031 (Ref. 15) asking the RP about its approach to radiation shield penetrations. The response outlines an approach to minimise radiological dose to workers which includes elimination of penetrations as far as possible, minimising radiation though positioning and size limitation of penetrations and isolating radiation paths by sealing gaps. I consider this to be a reasonable response which places an appropriate level of priority on eliminating penetrations where practicable to do so. The RP will need to demonstrate that the proposed approach is ALARP in later stages of GDA.

HVAC System Design

83. A high level description of the HVAC system is provided in PSR Chapter 22 (Ref. 2) including features for controlling the spread of airborne radioactive contamination. This includes minimisation of leakage from the radioactive gas collection system, directing the movement of air flow from lower to higher potential radioactive contamination levels and filtering before discharge.

4.4.2 Strengths

84. During my GDA Step 2 assessment of "Radiation Protection Measures", I have identified the following aspects which I consider to be strengths:

- A radiation and contamination zoning system is described which will adopt a graded approach in line with RGP.
- The PSR (Ref. 2) provides a useful introduction to the systems used for monitoring radiation and radioactive contamination.

4.4.3 Items that Require Follow-up

85. During my GDA Step 2 assessment of "Radiation Protection Measures" I have identified the following potential shortfalls that I will follow-up during Step 3 of GDA:

- The RP needs to clearly demonstrate how, from a Radiological Protection perspective, the hierarchy of control measures has been adequately applied to the UK HPR1000 generic design, with a focus on using engineering controls in the first instance (where demonstrated to be reasonably practicable). ONR expects personnel access to high dose rate areas is restricted, to prevent inadvertent radiation exposure.
- When specific radiological source terms have been developed for the UK HPR1000, a detailed consideration of the adequacy of the radiation shielding in the generic design, for the purpose of radiation dose optimisation, will be required. This will need to take into account any potential changes in radioactivity levels over the lifetime of the plant.

- Further information will be required on the design of the HVAC system, and the specific safety claims made on its function, which are related to radiological protection requirements.
- The PSR (Ref. 2) describes the systems designed to monitor the spread of radioactivity through systems and to detect abnormal levels of radioactivity and radioactive contamination. In the first instance, further information will be required on the measures taken to prevent the spread of radioactivity through UK HPR1000 HVAC and coolant systems.
- Further consideration of fault and accident conditions is required to assess potential radiation doses under fault conditions and to demonstrate that the radiological risk is adequately controlled and reduced SFAIRP.

4.4.4 Conclusions

86. Based on the outcome of my assessment of “Radiation Protection Measures”, I have concluded that the relevant information submitted by the RP is a suitable introduction to the types of radiation protection measures planned for UK HPR1000. I consider it is commensurate with the level of detail expected to be able to undertake a meaningful Step 2 assessment for this topic.

87. Nevertheless, I have also concluded that further work will be required by the RP to develop these aspects of the UK HPR1000 generic safety case. In particular, to show that the hierarchy of control measures has been adequately applied to radiation protection measures, with an appropriate level of reliance on engineered controls, which is demonstrably reasonably practical.

4.5 Personal Dose Monitoring and Dose Assessment

4.5.1 Assessment

88. The PSR Chapter 22 (Ref. 2) considers monitoring of personal dose from external radiation exposure using both passive and electronic dosemeters. The level of information provided on this is appropriate for Step 2.

89. The PSR Chapter 22 (Ref. 2) claims that internal radiation exposures will be estimated for example based on measured air concentrations and calculations. This is an acceptable position for the RP to take at Step 2 as a detailed breakdown of operator tasks is not yet required. Further information will be required on provisions for the monitoring of internal radiation doses where appropriate. In particular for tasks where there is the potential for significant intakes of radioactive material.

90. A collective dose target for the UK HPR1000 is still to be developed by the RP, but will be done during GDA. However, a high-level description is provided of how this will be optimised including using OPEX from Pressurised Water Reactors (PWRs) operating in China and international RGP. The FCG3 collective dose target value is 0.6 man-Sv per year, per unit. Once a collective dose target is developed for the UK HPR1000 design, and other metrics, such as dose-per-outage, ONR would expect the RP to demonstrate that these are broadly comparable to leading operational PWRs world-wide. Further information will also be required on how the individual dose targets described in the PSR Chapter 22 (Ref. 2) will be used.

91. Public radiation dose assessment is covered in the PSR Chapter 26 (Ref. 6). The EA is responsible for the regulation of public radiation doses during normal operation; however public radiation dose due to direct radiation shine is assessed by ONR. Chapter 26 outlines the approach for estimating radiation dose to the most exposed members of the public. The approach adopted is extremely simple, but uses conservative assumptions and gives adequate reassurance at Step 2 that public doses will be tolerable. A more robust demonstration will be needed for GDA Step 3.

92. The Interim Spent Fuel Store is not included within PSR Chapter 2 General Plant Description (Ref. 20) but it is stated that high level information will be included on this in later GDA submissions. This is an acceptable position for the RP to take for Step 2; however I will follow this up in Step 3 to ensure that enough information is provided to enable the impact on off-site radiation doses due to direct radiation shine to be adequately considered.

4.5.2 Strengths

93. During my GDA Step 2 assessment of "Personal Dose Monitoring and Dose Assessment", I have identified the following aspect which I consider to be a strength:

- The PSR considers the requirement to optimise the collective radiation dose for UK HPR1000, based on relevant OPEX and RGP.

4.5.3 Items that Require Follow-up

94. During my GDA Step 2 assessment of "Personal Dose Monitoring and Dose Assessment" I have identified the following potential shortfalls that I will follow-up during Step 3 of GDA:

- A collective dose target, and other dose metrics as appropriate, should be developed for the UK HPR1000. It should be demonstrated that these are broadly comparable to leading operational PWRs worldwide.
- When the UK HPR1000 source terms are fully developed, the direct radiation dose estimate to the most exposed member of the public needs to be calculated. This should use a more representative and precise methodology to ensure that direct radiation doses to the public are well characterised, ALARP and can be compared with the legal limit and guidance on single source constraints from IRR17 (Ref. 7), PHE advice on doses to members of the public from new NPPs (Ref. 23) and the Numerical Target 3 BSO from the SAPs (Ref. 9).

4.5.4 Conclusions

95. Based on the outcome of my assessment of "Personal Dose Monitoring and Dose Assessment" I have concluded that further information is required to develop the submission to demonstrate that potential doses to workers and members of the public are well characterised, ALARP and broadly comparable with RGP from around the world. The Step 2 submission provides a suitable introduction to this topic and is acceptable for this Step in the GDA process.

4.6 Out of Scope Items

96. The following items have been left outside the scope of my GDA Step 2 assessment of the UK HPR1000 for Radiological Protection.

- Safety categorisation and classification of SSCs. The reason for leaving this matter out of the scope of my GDA Step 2 assessment is that no information is provided on structures, systems and components with safety functions related to radiological protection in the radiological protection submissions. An assessment of the general approach to this by the RP is given in Ref. 21.
- Application of the ALARP principle to post accident access by mitigation staff. It is stated in the PSR Chapter 22 (Ref. 2) that adequate radiation protection measures against exposure to radiation and radioactive substance will be provided during normal operation and fault or accident conditions. However no additional information has been provided regarding radiation exposures to

mitigation staff following an accident in the GDA Step 2 submissions and so I could not complete a meaningful assessment.

- Application of ALARP to on site worker doses following DBA and DEC accidents. It is stated in the PSR Chapter 22 (Ref. 2) that doses to workers under accident conditions will be ALARP. At the time of writing, information was not provided that allowed a meaningful assessment of this claim. The approach that the RP will take to demonstrate that it meets ONR expectations in this area, for example with regard to SAPs Numerical Targets 5 and 6 (Ref. 9) is the subject of ongoing discussion between the RP and ONR.
- There are a number of high level claims in PCSR Chapter 24 (Ref. 18) related to design for decommissioning and to decommissioning planning and strategy. Chapter 24 and its associated documentation have been assessed by the Nuclear Liabilities Inspector and will not be discussed further here, however further detail on occupational exposure during the decommissioning phase will be required in GDA Step 3 as part of the Radiological Protection assessment.

97. It should be noted that the above omissions do not invalidate the conclusions from my GDA Step 2 assessment. During my GDA Step 3 assessment I will follow-up the above out-of-scope items as appropriate; I will capture this within my GDA Step 3 Assessment Plan.

4.7 Comparison with Standards, Guidance and Relevant Good Practice

98. In Section 2.2, above, I have listed the standards and criteria I have used during my GDA Step 2 assessment of the aspects of the UK HPR1000 related to Radiological Protection, to judge the adequacy of the preliminary safety case. In this regard, my overall conclusions can be summarised as follows:

- SAPs: In general, the claims made in the PSR Chapter 22 (Ref. 2) align with ONR's expectations as set out in the relevant SAPs (Ref. 9); however, further information and work is required in some areas to fully demonstrate this. I consider the RP's submissions to be acceptable for Step 2 and provide sufficient confidence that ONR's expectations, as set out in the relevant SAPs, should be met in the later stages of GDA. Table 1 provides further details.
- TAGs: In general, the claims made in the PSR align with ONR's expectations as set out in the relevant TAGs (Ref. 10); however further information and work is required in some areas to fully demonstrate this. I consider the RP's submissions to be acceptable for Step 2 and provide sufficient confidence that ONR's expectations, as set out in the relevant TAGs, should be met in the later stages of GDA.
- IRR17: In general, the claims made in the PSR align with the legal requirements as set out in the relevant regulations of IRR17 (Ref. 7); however further information and work is required in some areas to fully demonstrate this. I consider the RP's submissions to be acceptable for Step 2 and provide sufficient confidence that the requirements of IRR17 should be met in principle, during the later stages of GDA.

4.8 Interactions with Other Regulators

99. I have interacted with the Environment Agency in the assessment of off-site radiation exposure to the public due to direct radiation shine. This is addressed by the RP in Chapter 26 of the PSR (Ref. 6), and my Step 2 assessment of these aspects is presented in Section 4.6 of my report.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

100. During Step 2 of GDA, the RP submitted a PSR (Ref. 2) and other supporting references, which outline a preliminary nuclear safety case for the UK HPR1000. These documents have been formally assessed by ONR. The PSR together with its supporting references present at a high level the claims in the area of Radiological Protection that underpin the safety of the UK HPR1000.

101. During Step 2 of GDA I have targeted my assessment at the content of the PSR (Ref. 2) and its references that are of most relevance to the area of Radiological Protection; against the expectations of ONR's SAPs (Ref. 9) and TAGs (Ref. 10) and other guidance which ONR regards as RGP. From the UK HPR1000 assessment done so far, I conclude the following:

During my assessment I have identified some strengths in the RP's submissions. These can be summarised as follows:

- An awareness of GB legislative requirements is demonstrated, along with a more detailed understanding of requirements related to the need to demonstrate that occupational radiation exposures are ALARP.
- The PSR recognises that a radiological dose optimisation process is required to ensure doses to workers are ALARP, including optioneering and the use of feedback loops to assess the success of chosen options.
- The PSR provides high level examples of how the facility layout and equipment is designed with ALARP considerations in mind and demonstrates the application of lessons learned from the operation of predecessor plants such as the CPR1000.
- The documentation provided a useful high level introduction to how the source terms will be defined, employing RGP by using OPEX and theoretical. This gives an indication of which systems source terms will be developed for, and how they will be derived. This provides a suitable basis to develop the UK HPR1000 source terms.
- A radiation and contamination zoning system is described which will adopt a graded approach in line with RGP.
- The PSR Chapter 22 (Ref. 2) provides a useful introduction to the systems for monitoring radiation and contamination.

During my assessment I have identified areas which should be considered for follow up as part of the next Steps in the GDA process. These can be summarised as follows:

- A broader examination of the requirements of IRR17 (Ref. 7) needs to be carried out in Step 3, looking at requirements that may affect the design (see section 4.1.3).
- Further information is required on how radioactivity within the reactor design has been reduced SFAIRP through material choices, operating practices and chemistry control. In particular there is limited evidence available to demonstrate how operational practices and procedural controls which directly affect the source term have been adequately considered, to ensure radioactivity in the primary coolant is reduced SFAIRP (see section 4.2.3).
- The RP's ALARP methodology published so far is high level and general. More detail will be required in Step 3 on the application of ALARP to occupational exposure (see section 4.2.3).
- The outlined approach to developing the FCG3 source terms does not include actinides in the main radionuclide groups, on the basis that actinide concentration will be negligible. The evidence underpinning this has yet to be provided and will be required in Step 3 of GDA (see section 4.3.3).

- The RP has not yet defined source terms that can be shown to be applicable to the UK design. Development of the UK HPR1000 source term will be required in Step 3 of GDA, including definition of the assumptions used to adapt the FCG3 source term and further information on the RGP used to define the source term (see section 4.3.3).
- The submission should be developed to clearly demonstrate how the hierarchy of control measures has been applied to the design with a focus on using engineering controls in the first instance (see section 4.4.3).
- When a specific source term has been developed for the UK HPR1000 further consideration will be required on the use of shielding in the design for dose optimisation, taking into account any potential changes in radioactivity levels over the lifetime of the plant (see section 4.4.3).
- Further information will be required on the ventilation system and its role in radiological protection (see section 4.4.3).
- Further information will be required on the measures taken to prevent the spread of radioactivity through the HVAC and coolant systems and where this information is discussed in other technical areas there should be clear consideration of the impact on radiological protection (see section 4.4.3).
- Further consideration of fault and accident conditions is required to assess potential doses under fault conditions and to demonstrate that the radiological risk is adequately controlled (see section 4.4.3).
- A collective dose target, and other dose metrics as appropriate, should be developed for the UK HPR1000 and it should be demonstrated that these are broadly comparable to leading operational PWRs of a similar design (see section 4.5.3).
- When the UK HPR1000 source term is fully developed the direct radiation dose estimate to the most exposed member of the public needs to be calculated using a more representative and precise methodology to ensure that direct radiation doses to the public are well characterised, reduced SFAIRP and can be compared with the legal limit and guidance on single source constraints from IRR17 (Ref. 7), PHE advice on doses to members of the public from new NPPs (Ref. 23) and the Numerical Target 3 BSO from the SAPs (Ref. 9) (see section 4.5.3).

102. My understanding of the UK HPR1000 technology is high level at the moment, but is commensurate with the level of detail required to undertake a meaningful Step 2 assessment. It will be developed as GDA progresses. The visit I was able to make to a similar operational plant in China gave me a very good insight into how key operational Radiological Protection controls could work for UK HPR1000, in practice.

103. Overall, during my GDA Step 2 assessment, I have not identified any fundamental safety / security shortfalls in the area of Radiological Protection that might prevent the issue of a Design Acceptance Confirmation (DAC) for the UK HPR1000 design.

5.2 Recommendations

104. My recommendations are as follows.

- Recommendation 1: ONR should consider the findings of my assessment in deciding whether to proceed to Step 3 of GDA for the UK HPR1000.
- Recommendation 2: All the items identified in Step 2 as important to be followed up should be included in ONR's GDA Step 3 Radiological Protection Assessment Plan for the UK HPR1000.
- Recommendation 3: All the relevant out-of-scope items identified in sub-section 4.7 of this report should be included in ONR's GDA Step 3 Radiological Protection Assessment Plan for the UK HPR1000.

6 REFERENCES

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NS-TAST-GD-005 (Rev 7) – ONR Guidance on the demonstration of ALARP
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Table 1: Relevant Safety Assessment Principles Considered During the Assessment

SAP No and Title	Description	Interpretation	Comment
FP.3 Optimisation of protection	"Protection must be optimised to provide the highest level of safety that is reasonably practicable."	This principle sets the expectation that protection will be optimised, which from a radiological protection perspective can be considered as dose optimisation and application of ALARP.	Application of ALARP and dose optimisation is addressed (see section 4.2 and 4.5 respectively). This should be developed in the next Steps of GDA, but the information provided so far gives a good indication that SAP requirements can be met.
FP.4 Safety assessment	"Duty holders must demonstrate effective understanding and control of the hazards posed by a site or facility through a comprehensive and systematic process of safety assessment."	In radiological protection this can considered as understanding the sources of radiation / contamination and the measures in place to control them.	The source term for the design is not defined yet so this SAP is not yet fully met. Radiation protection measures for controlling the hazard are addressed (see section 4.4) but should be developed in the next Steps of GDA.
FP.6 Prevention of accidents	"All reasonably practicable steps must be taken to prevent and mitigate nuclear or radiation accidents."	In radiological protection this should be considered for radiation accidents.	High level information is provided on radiological risk assessment for accident conditions; however limited information is available on preventing accidents. Further work is required in this area and the SAP requirement is not yet fully met.
FP.8 Protection of present and future generations	"People, present and future, must be adequately protected against radiation risks."	Consideration should be given of radiation risk throughout the lifetime of the plant and beyond.	Protection of workers and the public is considered for the present but there is limited consideration of people in the future. Further development in this area will be required but the information provided so far gives a good indication that SAP requirements can be met.
RP.1 Normal operation (Planned Exposure Situations)	"Adequate protection against exposure to radiation and radioactive substances should be provided in those parts of the facility to which access is permitted during normal operation."	This principle sets out the expectations for limiting exposure to radiation including the use design features, instrumentation and PPE. It also covers estimation, monitoring and assessment of doses.	There is consideration of this within the radiological protection submission and this should be developed in the next Steps of GDA. The information provided so far gives a good indication that SAP requirements can be met.
RP.2 Fault and accident conditions (Emergency	"Adequate protection against exposure to radiation and radioactive contamination should be provided in those parts of the facility	This principle covers radiological protection expectations for fault and accident conditions and also sets out the requirement for emergency exposure dose levels.	There is limited information provided in the submission for fault and accident conditions. Further work in this area is required. It has not been demonstrated that the SAP requirements are likely to be met, due to a lack of

Exposure Situations)	that will need to be accessed during faults or as part of accident management. This should include prevention or mitigation of accident consequences."		information provided.
RP.3 Designated areas	"Where appropriate, designated areas should be further divided, with associated controls, to restrict exposure and prevent the spread of radioactive material."	This principle sets out the framework for designated areas including further division of areas based upon the levels of radiation and contamination measured and / or expected. There should be appropriate controls commensurate with the level of hazard.	The approach for radiation zoning is addressed (see section 4.4). This should be developed in the next Steps of GDA including further consideration of access controls but the information provided so far gives a good indication that SAP requirements can be met.
RP.4 Contaminated areas	"Effective means for protecting persons entering and working in contaminated areas should be provided."	Levels of contamination should be kept ALARP and there should be means for monitoring and controlling the spread of surface and airborne contamination.	The means for monitoring contamination are addressed (see section 4.4). This should be developed in the next Steps of GDA, particularly in relation to controlling the spread of contamination.
RP.5 Decontamination	"Suitable and sufficient arrangements for decontaminating people, the facility, its plant and equipment should be provided."	This principle covers the expectation for monitoring and decontaminating locally or using a centralised facility where appropriate. This SAP also covers the use of remote handling devices and enclosures to prevent the spread of contamination.	The means for monitoring contamination is addressed (see section 4.4) but limited information has been provided on decontamination so further work will be required in this area but the information provided so far gives a good indication that SAP requirements can be met..
RP. 7 Hierarchy of control measures	"The duty holder should establish a hierarchy of control measures to optimise protection in accordance with IRR17."	This principle sets out the requirement for controlling doses using engineering means first and foremost and then using supporting systems of work followed by PPE.	Engineered controls are considered (see section 4.4); however further consideration is required on how the hierarchy of control measures is applied, particularly in the area of access control to high dose rate areas in order to demonstrate that the SAP requirements are likely to be met.
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."	This principle sets out the requirement for a design that avoids radiological hazards rather than controlling them.	Further development of the submission is required to demonstrate how radiological hazards have been avoided in the first instance before controls are considered but the information provided so far gives a good indication that SAP requirements can be met.