Health and Safety Executive

NUCLEAR DIRECTORATE

GENERIC DESIGN ASSESSMENT – NEW CIVIL REACTOR BUILD

STEP 3 RADIOLOGICAL PROTECTION ASSESSMENT OF THE EDF AND AREVA UK EPR

DIVISION 6 ASSESSMENT REPORT NO. AR 09/030-P

HSE Nuclear Directorate
Redgrave Court
Merton Road
Bootle
Merseyside L20 7HS

EXECUTIVE SUMMARY

Introduction

My report presents the findings of the radiological protection assessment of the EDF and AREVA UK EPR Pre-Construction Safety Report (PCSR) undertaken as part of Step 3 of the HSE Generic Design Assessment (GDA) process. In this report, "radiological protection" and "radiation protection" are taken to be synonymous. No radiological protection assessment of the UK EPR design was carried out during Step 2, and the assessment work was initiated after the start of Step 3. Therefore, radiological protection has been studied in greater depth than required for Step 2, but not in as much detail as would be expected for Step 3; for example, the radiological consequence assessment elements of the Level 3 Probabilistic Safety Analysis (PSA) have still to be examined.

My report provides an overview of: the safety case presented in the PCSR; the standards and criteria adopted in the assessment; and an assessment of the claims and arguments provided within the safety case.

Scope of assessment carried out

Radiological protection was addressed in Chapter 12 of the PCSR and covered: radiation protection requirements; radiation protection approach; definition of radioactive sources in the primary circuit; radiation protection measures; dose uptake optimisation; and post-accident accessibility. Some areas of work were still ongoing by the requesting party (RP), for example, to further refine dose uptake optimisation; these areas were clearly identified within the PCSR and supporting documentation.

My assessment strategy was outlined in the Project Initiation Document (PID) entitled Generic Design Assessment, Step 3, Radiation Protection. The PID explained that the GDA process would review the overall safety of the design, and the assessment of radiological protection aspects would consider: occupational doses during normal operation, including outages and maintenance work; doses to members of the public during normal operation, in particular, doses due to direct radiation; and occupational doses and doses to members of the public during accident conditions. In addition, the PID recognised that some areas would not be covered in Step 3, and that much of the work would have to be undertaken in Step 4. The standards and criteria used for the assessment were the Ionising Radiations Regulations 1999, Radiation (Emergency Preparedness and Public Information) Regulations 2001, Nuclear Directorate's (ND) Safety Assessment Principles (SAPs), and ND's Technical Assessment Guides (TAGs) that support those principles relevant to radiological protection.

My assessment concentrated on occupational and public radiation exposure during normal reactor operation, such as electricity generation, maintenance and planned activities (e.g. refuelling). A key factor of the assessment was to consider whether the principles of radiological protection, namely justification, optimisation and limitation, had been applied (justification is not regulated by HSE and is not considered in the SAPs). My main focus was on optimisation and to assess whether exposure to radiation was restricted so far as was reasonably practicable (i.e. as low as reasonably practicable, or ALARP). During my assessment I raised a number of technical queries relating to requests for references, points for clarification, and further information on dose uptake optimisation.

I will assess the robustness of potential dose uptake and its optimisation and limitation based on evidence provided by the RP during Step 4, focusing on, in particular, occupational exposure associated with the fuel route, shielding, ventilation, contamination control, plant radiation monitoring system, and waste handling and decommissioning. I will also focus on occupational and public radiation exposure during accident conditions. This future work will involve working closely with assessors in other topic areas in ND and the Environment Agency.

Conclusions

I conclude that the RP has provided a reasonable safety analysis of radiological protection during normal reactor operation, and that the claims and arguments for radiation doses being ALARP are adequate for GDA Step 3.

No regulatory observations, regulatory issues or potential exclusions have been identified to date. Overall, I see no reason why on radiological protection grounds the UK EPR design should not proceed to GDA Step 4.

LIST OF ABBREVIATIONS

ACOP	Approved Code Of Practice
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BMS	(Nuclear Directorate) Business Management System
BSL	Basic Safety Limit
BSO	Basic Safety Objective
CVCS	Chemical Volume and Control System
EA	The Environment Agency
EDF and AREVA	Electricité de France SA and AREVA NP SAS
EDPI	Initial Predicted Dose Estimate
EDPO	Optimised Predicted Dose Estimate
GDA	Generic Design Assessment
HPA RPD	Health Protection Agency – Radiation Protection Division
HSE	The Health and Safety Executive
HSWA74	The Health and Safety at Work etc Act 1974, as amended
IAEA	The International Atomic Energy Agency
IRR99	The Ionising Radiations Regulations 1999
MDEP	Multinational Design Evaluation Programme
ND	The (HSE) Nuclear Directorate
NPP	Nuclear Power Plant
NRPB	Nuclear Radiological Protection Board
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
PID	Project Initiation Document
PRMS	Plant Radiation Monitoring System
PSA	Probabilistic Safety Analysis
PWR	Pressurised Water Reactor
REPPIR	The Radiation (Emergency Preparedness and Public Information) Regulations 2001
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RSBSSEWD	The Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000
SAP	Safety Assessment Principle
SFAIRP	So Far As Is Reasonably Practicable

LIST OF ABBREVIATIONS

TAG	(Nuclear Directorate) Technical Assessment Guide
TSC	Technical Support Contractor
WENRA	The Western European Nuclear Regulators' Association

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1 INTRODUCTION

1 The Nuclear Directorate's (ND's) Generic design Assessment (GDA) process calls for a step-wise assessment of the Requesting Party's (RP's) safety submission. Steps 2, 3 and 4 deal with claims, arguments and evidence, respectively.

2 My report presents the findings of the radiological protection assessment of the EDF and AREVA UK EPR design contained in the Pre-Construction Safety Report (PCSR) (Ref. 1) undertaken as part of Step 3 of the HSE GDA process. In this report, "radiological protection" and "radiation protection" are taken to be synonymous. This assessment has been undertaken in line with the requirements of the Business Management System (BMS) document AST/001 (Ref. 2) and its associated guidance document G/AST/001 (Ref. 3). AST/001 sets down the process of assessment within ND and explains the process associated with sampling of safety case documentation. The Safety Assessment Principles (SAPs) (Ref. 4) have been used as the basis for the assessment of radiological protection associated with UK EPR design, and provide a framework for making consistent regulatory judgements on nuclear safety cases; the major SAPs used are identified in Table 1. A number of Technical Assessment Guides (TAGs) have also been used to inform the process of assessment of the UK EPR design against the SAPs; these are also identified in Table 1. Ultimately, the goal of assessment is to reach an independent and informed judgment on the adequacy of a nuclear safety case.

3 Unlike many technical areas, no radiological protection assessment of the UK EPR design was carried out during Step 2. In addition, the work on the radiological protection assessment was initiated approximately 10 months after the start of Step 3. These points taken together mean that radiological protection has been studied in greater depth than required for Step 2, but not in as much detail as would be expected for Step 3. The majority of the radiological protection assessment work and all that relating to the Level 3 Probabilistic Safety Analysis (PSA) assessment work will be carried out during Step 4.

4 My report summarises the Step 2 / Step 3 assessment to date on Chapter 12 of the PCSR (Ref. 1) which was Issue 02 of the PCSR that was submitted in June 2009. My report concentrates on occupational and public exposure to ionising radiation during normal reactor operation, such as electricity generation, maintenance and planned activities (e.g. refuelling). Areas to consider during Step 4, such as occupational exposure to ionising radiation associated with the fuel route, waste handling, shielding, ventilation, contamination control, Plant Radiation Monitoring System (PRMS), decommissioning, and occupational and public radiation exposures during accident conditions, have also been identified.

5 Regulation of public radiation exposure is shared between the Environment Agency (EA) (in England and Wales) and HSE. The EA leads on doses to the public resulting from discharges of radioactive waste into the environment during normal operation, and so this topic area is outside the scope of my assessment report. ND leads for HSE on doses to the public resulting from direct radiation (i.e. direct radiation originating from within the site boundary) during normal operation. In contrast to this, for public doses resulting from accidents, ND leads for all pathways (i.e. doses resulting not only from direct radiation originating from within the site boundary, but also from radioactive substances escaping into the environment).

2 NUCLEAR DIRECTORATE'S ASSESSMENT

2.1 Requesting Party's Safety Case

6 Radiological protection requirements were contained in Chapter 12 (entitled Radiation Protection) of the PCSR (Ref. 1). Sub-Chapters 12.0 to 12.5 dealt with radiation protection requirements, radiation protection approach, definition of radioactive sources

in the primary circuit, radiation protection measures, dose uptake optimisation, and post-accident accessibility, respectively.

2.1.1 Radiation Protection Requirements

7 Sub-Chapter 12.0, Radiation Protection Requirements, outlined the relevant regulatory requirements in terms of international recommendations (Ref. 5), the European Directive which takes account of those international recommendations (Ref. 6), and the legislation that implements that Directive in England and Wales which is relevant to nuclear plant. This legislation was as follows.

- The Ionising Radiations Regulations 1999 (IRR99) (Ref. 7).
- The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) (Ref. 8).
- The Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000, (RSBSSEWD) (Ref. 9); RSBSSEWD is enforced by EA.

8 Sub-Chapter 12 also summarised definitions of zoning for areas to describe ranges of radiation dose rates, airborne contamination and surface contamination within the workplace.

2.1.2 Radiation Protection Approach

9 Sub-Chapter 12.1, Radiation Protection Approach, outlined the principles of radiation protection (justification, optimisation and limitation) and proposals to minimise radiation exposure and plant radioactivity levels by optimising the plant radioactivity inventory and shielding provisions. It stated that the individual dose limit for the plant would be 10 mSv over 12 consecutive months (this was a company operational dose limit, not a legal dose limit), and the collective dose target would be 0.35 person-Sv per year per unit (i.e. per reactor). The collective dose target was based on current operational feedback from French Nuclear Power Plants (NPPs). It was averaged over 10 years to take account of two refuelling only outages, three normal refuelling outages (involving partial inspection) and one 10-year in-service inspection outage during the 10-year cycle. The main measures to optimise doses and to comply with this limit and target were summarised as follows.

- Taking account of feedback and best practice from the best operational NPPs.
- Reducing equipment maintenance requirements by choosing reliable and suitable materials (taking into account conventional safety and human factors).
- Choosing materials to reduce activated corrosion products (mainly cobalt isotopes).
- Taking advantage of improvements in fuel assembly technology leading to fewer cladding defects and reduced risk of fission products entering the primary circuit.

2.1.3 Definition of Radioactive Sources in the Primary Circuit

10 Sub-Chapter 12.2, Definition of Radioactive Sources in the Primary Circuit, explained that realistic source term data (from corrosion product and fission product activities) were used to estimate occupational doses, whereas more conservative data were used to define the biological protection design source term (used as a design parameter for buildings, systems and shielding provisions). This Sub-Chapter summarised the source of the radionuclides in the primary circuit, and identified 33 radionuclides whose specific concentrations affected radiological protection under normal operation.

2.1.4 Radiation Protection Measures

11 Sub-Chapter 12.3, Radiation Protection Measures, provided greater detail on zoning for radiation than had been provided in Sub-Chapter 12.0, including zoning required by IRR99 (Ref. 7) in terms of controlled areas and supervised areas. It also covered shielding provisions, ventilation, and provision for monitoring rooms, monitoring employees, and monitoring the unit through the PRMS.

2.1.5 Dose Uptake Optimisation

12 Sub-Chapter 12.4, Dose Uptake Optimisation, outlined the method for detailed dose prediction analysis. The key factors were as follows.

- Collecting dose uptake statistics from the best performing 1300 MWe NPPs.
- Identifying activities with high dose uptake during normal operation and outages, and selecting them for detailed dose optimisation.
- Predicting dose uptake following detailed dose optimisation, taking into account the type of outage.
- Predicting the annual collective dose over a 10-year cycle.

13 This Sub-Chapter identified the reference dose (i.e. the collective dose from the best-performing French NPP), identified work activities that together were responsible for 50% of that collective dose, and optimised those doses to predict dose estimates. Those dose estimates were identified in three ways.

- Initial Predicted Dose Estimate (EDPI) that considered proven modifications.
- Optimised Predicted Dose Estimate (EDPOa) that considered proven modifications plus modifications being studied.
- Optimised Predicted Dose Estimate (EDPOc) that considered proven modifications, modifications being studied plus modifications still to be studied.

14 The work activities that together were responsible for 50% of the collective dose were as follows.

- Thermal insulation operations.
- Worksite logistics.
- Valve activities.
- Steam generator worksite.
- Worksite for opening and closing the reactor vessel.
- Fuel posting out worksite.
- Waste treatment operations.

15 The results of the optimisation study were that the reference dose was 0.440 person-Sv per year per unit, EDPI was 0.361 person-Sv per year per unit, EDPO was 0.345 person-Sv per year per unit, and predicted dose target estimate was 0.331 person-Sv per year per unit. These results were consistent with the collective dose target of 0.35 person-Sv per year per unit that was stated in Sub-Chapter 12.1. These doses were averaged over 10 years to take account of the three types of outage described in Section 2.1.2 above.

2.1.6 Post Accident Accessibility

16 Sub-Chapter 12.5, Post Accident Accessibility, defined the systems, rooms and components for which access would be required in post-accident conditions for long-term cooling of the plant and fuel pond (over a period of one year), and identified work that would be necessary before access could take place. It also identified relevant legislation (IRR99, (Ref. 7); REPPIR, (Ref. 8); The Nuclear Installations Act 1965, as amended, (Ref. 10)), and upper dose levels for personnel involved in intervention and in saving life.

2.2 Standards and Criteria

17 My assessment strategy for Step 3 was outlined in the PID (Ref. 11). This strategy included assessing the RP's PCSR (Ref. 1) and supporting documentation against requirements, standards and criteria identified in legislation, SAPs and TAGs dealing with radiological protection. The PID identified the principles that were of greatest relevance to radiological protection in the SAPs, and provided references to TAGs that support those principles. In addition, the PID tracked the SAPs against international reference levels and fundamental principles in documentation provided by the Western European Nuclear Regulators' Association (WENRA) and International Atomic Energy Agency (IAEA), respectively. These SAPs are listed in Table 1.

18 The key piece of legislation was IRR99 (Ref. 7) which provided the framework for radiological protection. Another important piece of legislation was REPPIR (Ref. 8) which dealt with optimisation of potential radiation doses to intervention personnel during radiation emergencies. In the SAPs, the key fundamental principles that had some relevance to radiological protection were FP3 to FP8. The key radiation protection principles (RP1 to RP6) were for normal operation, accident conditions, designated areas, contaminated areas, decontamination, and shielding. All the numerical targets and legal limits (NT.1 Targets 1 to 9, and NT.2) were relevant to a degree. Some of these principles, targets and limits were addressed during Step 3, whilst others will be dealt with during Step 4.

19 In addition, the PID (Ref. 11) also identified other principles in the SAPs that had relevance to radiological protection to a lesser degree in topic areas dealing with safety cases, siting (not a direct issue for the GDA process), key engineering principles, integrity of metal components and structures, layout, control of nuclear matter, control and instrumentation of safety related systems, containment and ventilation, heat transport systems, radioactive waste management, and decommissioning. These will be considered as appropriate during Step 4.

20 The framework underpinning all of the standards and criteria above are the principles of radiological protection, namely, justification, optimisation and limitation.

- Exposures to radiation should be justified. Justification is not regulated by HSE and is not considered in the SAPs.
- Exposures to ionising radiation should be optimised. Radiation exposures must be restricted "so far as is reasonably practicable" (SFAIRP) under IRR99, that is, doses should be "as low as reasonably practicable" (ALARP). In this report the UK term "ALARP" is taken to be synonymous with the international term "ALARA" ("as low as reasonably achievable") and with SFAIRP.
- Exposures to ionising radiation should be limited in that they must not exceed the statutory dose limits in IRR99. Clearly this should not be an issue for modern nuclear plant under normal operation (as is indeed the case; see Annex 1).

21 The principal standards and criteria for judging whether ALARP has been met are the Approved Code of Practice (ACOP) and Guidance to IRR99 (entitled Work with Ionising Radiation) (Ref. 12), supplemented by additional guidance on HSE's website (including the TAGs). In addition, IRR99 require a hierarchical approach to control exposure: first, exposures should be restricted by engineered controls and design features (and in addition, by the provision and use of safety features and warning devices); secondly, by supporting systems of work; and thirdly and lastly, by the provision of personal protective equipment.

22 The principal standards and criteria for judging whether ALARP has been met for intervention personnel during accident conditions is the Guide to REPPIR (Ref. 13), supplemented by additional guidance on HSE's website (Ref. 14). The National Radiological Protection Board (NRPB), now the Radiation Protection Division of the Health Protection Agency (HPA RPD), has also published guidance on controlling doses for people on site during radiation accidents (Ref. 15).

23 When judging against the ALARP principle, caution should be used to distinguish between dose and risk. The general duties of employers to their employees and other persons in Sections 2 and 3, respectively, of the Health and Safety at Work etc Act 1974, as amended (HSWA74) (Ref. 16), refer to risks, as do the expectations in many of the SAPs (Ref. 4). However, the duties of radiation employers in IRR99 and expectations in some of the SAPs refer to radiation exposures and not just to the implied risk. The hierarchy of risk in IRR99 (Ref. 7) is also applicable here, as the ACOP to regulation 8 advises radiation employers to give priority to improving engineering controls and adopting other means of restricting exposure over and above dose sharing between employees (Ref. 12). If a choice has to be made between restricting exposures to individuals or to groups of employees then priority should always be given to restricting exposures to individuals. In contrast to this, under accident conditions, the risk is determined by both the magnitude of the dose and the probability of its occurrence. For the purposes of ALARP, the risk of harm to an individual from whole-body exposure is taken to be directly proportional to that dose.

24 The ALARP principle applies to the exposure of members of the public. As explained in Section 1 above, the regulation of public radiation exposure during normal reactor operation is shared between EA and HSE, where IRR99 (Ref. 7) is enforced by ND on behalf of HSE, and RSBSSEWD (Ref. 9) is enforced by EA. IRR99 (Ref. 7) require dose constraints to restrict exposure to ionising radiation at the planning stage where it is appropriate to do so. The guidance to IRR99 (Ref. 12) advises that a constraint for a single new source should not exceed 0.3 mSv per year for members of the public. This is reinforced in the SAPs (Ref. 4) in relation to NT.1 Target 3, and advises that HSE's view is that a single source should be interpreted as a site under a single dutyholder's control, since this is an entity for which radiological protection can optimised as a whole. However, the HPA RPD has recently recommended that doses to members of the public from new NPPs should be constrained to 0.15 mSv per year (Ref. 17).

25 The ALARP principle also applies to manufacturers etc. Section 6 of HSWA74 (Ref. 16) places general duties on manufacturers etc. as regards articles and substances for use at work, and duties on any person who designs, manufactures, imports or supplies any article for use at work. Where that work is with ionising radiation, the duty is modified to apply to articles for use at work by IRR99, regulation 31 (Ref. 7). This requires manufacturers etc to apply the ALARP principle, in that there is a duty to ensure that any such article is so designed and constructed as to restrict SFAIRP the extent to which employees and other persons are, or are likely to be, exposed to ionising radiation. Therefore, the requirement in law to keep radiation exposures ALARP applies not only to the licensee of a NPP, but also to the designer of that NPP.

2.3 Nuclear Directorate Assessment

2.3.1 Assessment Strategy

26 My assessment strategy was outlined in the PID (Ref. 11). The PID explained that the GDA process would review the overall safety of the design, and the assessment of radiological protection would cover the following topic areas.

- Occupational doses during normal operation, including outages and maintenance work.
- Doses to members of the public during normal operation, in particular, doses due to direct radiation originating from within the site boundary.
- Occupational doses and doses to members of the public during accident conditions.

27 The PID recognised that some areas would not be covered in Step 3, and that much of the work would have to be undertaken in Step 4. In addition, the PID explained that it would be necessary to work closely with assessors in other topic areas during both Step 3 and Step 4, such as PSA, deterministic safety analysis (fault studies), reactor chemistry, radioactive waste management, decommissioning, mechanical engineering, human factors, public exposures, and control and instrumentation.

28 In addition, much of radiological protection depends on detailed design, and so conclusions drawn at this stage have to be provisional until the design is finalised. Also, some matters may not be wholly appropriate for GDA, and would also need to be addressed in Phase 2 by the licensee. In such cases, the design would need to be sympathetic to the needs of the licensee (e.g. allowing sufficient space to allow erection of temporary shielding in locations where provision of permanent shielding may not be ALARP).

29 In applying expert judgement when assessing against the standards and criteria outlined in Section 2.2, I have taken account of radiation exposure control achieved at Sizewell B NPP and other relevant NPPs outside the UK, allowing for factors such as the age of the facilities.

2.3.2 Scope of Assessment

30 My assessment concentrated on occupational and public radiation exposure during normal reactor operation, such as electricity generation, maintenance and planned activities (e.g. refuelling). A key factor of the assessment was to consider whether the principles of radiological protection, namely justification, optimisation and limitation, had been applied (justification is not regulated by HSE and is not considered in the SAPs). My main focus was on optimisation and to assess whether exposure to radiation was ALARP.

31 My assessment considered claims and arguments made in the submission for GDA Step 3, and challenge to the supporting evidence will be undertaken during Step 4. Claims, arguments and evidence during accident conditions will be undertaken during Step 4.

2.3.3 Summary of Assessment

32 The fundamental principles are broad in their application and meeting their expectations cannot be satisfied by radiological protection assessment alone. Nevertheless, radiological protection may contribute to those expectations as laid out in the SAPs (Ref. 4). My assessment concentrated on occupational and public radiation exposure during normal reactor operation, and four of the eight fundamental principles were relevant (Fundamental Principles 3, 4, 5 and 8). Five of the six radiation protection principles

(Radiation Protection 1, 3, 4, 5 and 6), both the numerical target principles (NT.1 and 2), and three of the nine targets within NT.1 that identified Basic Safety Levels (BSLs) and Basic Safety Objectives (BSOs) (Targets 1, 2 and 3), were relevant to normal reactor operation.

33 My assessment was in two parts, the main part on optimisation, and the smaller part on limitation. Optimisation began with a discussion of the radiation sources in the primary circuit, followed by restriction of exposure by design (which included designated areas, shielding, contaminated areas and decontamination), and restriction of exposure by work activities (which included the optimisation process for work activities, optimisation of high dose work activities, and time at risk). Limitation covered legal dose limits under IRRs (Ref. 7), dose constraints, BSLs and BSOs.

34 In my opinion, the claims for all the areas on optimisation are appropriate with the exception of decontamination (see Section A1.1.3.2.4 in Annex 1) and optimisation for "jumpers" (whose work activity involved person-entry in the channel head to install nozzle dams, humidity detectors, etc. and whose radiation dose was measured in seconds, see Section A1.1.3.3.3 in Annex 1). However, a proportion of the responsibility for both of these topic areas may lie with the licensee in the future. In my opinion, the arguments for all of the areas that I assessed are adequate. Assessment of arguments for decontamination, shielding and optimisation for "jumpers" will be undertaken during Step 4. Evidence to underpin the arguments in all the areas will be assessed in Step 4 in liaison with assessors in other topic areas, as appropriate.

35 In my opinion, in the unlikely event that the work activity carried out by "jumpers" could not be undertaken by any other means, then this matter may develop into a Regulatory Observation (RO) during Step 4 since control of exposure in timeframes measured in seconds is difficult to manage and the application of the ALARP principle is difficult to demonstrate.

36 Other principles in the SAPs (Ref. 4) that had relevance to radiological protection to a lesser degree in other topic areas were identified in the PID (Ref. 11) as minor applicable SAPs, and I will consider these as appropriate during Step 4.

37 On public exposure, the UK EPR design complied with dose limits in IRR99 (Ref. 7) and requirements for maximum doses to members of the public under RSBSSEWD (Ref. 9). No estimated doses to members of the public during normal operation were presented in Chapter 12 of the PCSR (Ref. 1). Instead, these doses were presented in Chapter 11 of the Pre-Construction Environmental Report (PCER) (Ref. 18). These doses were well below the BSL and a little above the BSO for NT.1 Target 3, and well below the maximum doses in HPA RPD's recent recommendations on public exposure (Ref. 17). In my opinion, the claims for public exposure from direct radiation originating from within the site boundary during normal operation are appropriate. The arguments that underpin those claims, and evidence to substantiate those arguments, will be secured and assessed for estimated doses to the public resulting from direct radiation originating from within the site during Step 4. I will carry out my assessment in liaison with assessors in EA who lead on discharges of radioactive waste into the environment during normal operation.

38 My assessment did not include radiological protection during accident conditions and radiological consequence assessment elements of Level 3 PSA. Claims, arguments and evidence to underpin those arguments will be assessed during Step 4 in liaison with assessors in other topic areas, as appropriate.

2.3.4 Progress against PID

39 The PID (Ref. 11) recognised that some areas would not be covered in Step 3, and that the majority of the work would have to be undertaken during Step 4. Consequently, the

key fundamental principles that had some relevance to radiological protection (FP3 to FP8), the radiation protection principles (RP1 to RP6), and all the numerical targets and legal limits (which were relevant to a degree), were included and identified as spanning both Step 3 and Step 4. Progress of my assessment regarding claims and arguments for the principles, targets and limits are summarised in Table 2.

2.3.5 Follow-up of Issues from Step 2

40 This was not appropriate for my assessment since no assessment on radiological protection was carried out during Step 2.

2.3.6 Step 3 Requirements in HSE GDA Guidance

41 The requirements for the RP in Step 3 are set out in paras 3.1 to 3.13 of the HSE GDA guidance (Ref. 19). I have assessed the PCSR and supporting documentation against this guidance in so far as it applies to radiological protection, and from the assessment undertaken to date, the RP has met these requirements (see Annex 1).

42 My assessment has met Step 3 requirements specified in the HSE GDA Guidance (Ref. 19), paras 3.14, 3.15, 3.17, 3.18, 3.20, 3.22 and 3.23, as follows.

- Para. 3.14 (on UK EPR design meeting the RP's design safety criteria) is covered in Sections A1.1.3.3.1, A1.1.3.3.2 and A1.1.3.3.3 in Annex 1 in so far as it applies to dose optimisation for radiological protection.
- Para. 3.15 (on an initial assessment of the scope and extent of the arguments) is covered in part by this report. Areas where assessment of arguments will be covered in Step 4 are summarised in Sections 2.3.3, 2.3.4 and 2.3.9.
- Para. 3.17 (on reviewing work by overseas regulators) is covered in Section 2.3.7.
- Para. 3.18 (on deciding on scope and plan of further assessment) is covered in Section 2.3.9.
- Para. 3.20 (on research needs and contract support) is covered in Section 2.3.10.
- Para. 3.22 (on additional regulatory verification and analysis) is covered by the Technical Queries (TQs) raised to date, and by matters raised throughout my assessment report. Additional regulatory verification and analysis will be undertaken during Step 4 on matters raised to date plus other topic areas deferred to Step 4, such as the fuel route.
- Para. 3.23 (on the overall design being balanced to the overall risk) is covered by Sections A1.1.3.3.1 and A1.1.4 in Annex 1 in so far as it applies to radiological protection.

2.3.7 Overseas Regulator Information

43 A preliminary meeting between ND, EA and regulators from the USA to discuss initial views on radiological protection and waste management regarding the UK EPR design was held during Step 3. An initial meeting with regulators from Canada, China, Finland, France and USA to discuss radiological protection and waste management regarding the UK EPR design is being planned which will take place early in Step 4 through the EPR Working Group of the Multinational Design Evaluation Programme (MDEP). It is likely that further meetings with overseas regulators through MDEP will take place during Step 4.

2.3.8 ALARP Considerations

44 The bulk of my assessment dealt with considering whether the ALARP principle had been applied to occupational and public doses during normal reactor operation. Other assessors have looked at accident risk, and I will be contributing to the analysis of Level 3 PSA with regard to plume dispersion modelling and dose consequences during Step 4.

2.3.9 Plans for Step 4 Assessment

45 In Step 4, I will re-visit my Step 3 assessment in light of detailed evidence submitted by the RP and will assess the robustness of that evidence for potential dose uptake. I will focus on areas not covered in Step 3, such as occupational exposure associated with the fuel route, shielding, ventilation, contamination control, PRMS, and waste handling and decommissioning. I will also focus on optimisation for "jumpers". In addition, I will assess occupational and public radiation exposure during accident conditions.

46 I will carry out this assessment in consultation with assessors in ND and EA in other topic areas, such as PSA, deterministic safety analysis (fault studies), reactor chemistry, radioactive waste management, decommissioning, mechanical engineering, human factors, public exposures, and control and instrumentation, as necessary.

2.3.10 Research

47 ND has commissioned a research project with a Technical Support Contractor (TSC) to carry out a review of developments in good practice used in pressurised water reactors to minimise radiation doses and radioactive waste over the past 10 years. This project involves ND assessors in radioactive waste management, radiological protection and reactor chemistry. I will use the findings of this review to inform parts of my assessment during Step 4.

48 I will set up contracts with TSCs, as necessary, during Step 4 to provide independent verification and analysis in areas such as shielding, ventilation, PRMS, and plume dispersion modelling and dose consequences during accident conditions.

2.3.11 Regulatory Observations and Regulatory Issues

49 I have not identified any ROs or Regulatory Issues (RIs) during my assessment to date. However, in the unlikely event that the work activity carried out by "jumpers" could not be undertaken by any other means, then this matter may develop into a RO during Step 4 since control of exposure in timeframes measured in seconds is difficult to manage and the application of the ALARP principle is difficult to demonstrate.

2.3.12 Potential Exclusions

50 I have not identified any potential exclusions during my assessment to date.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

51 Much of radiological protection depends on detailed design, and so conclusions drawn at this stage have to be provisional until the design if finalised. Also, some matters may not be wholly appropriate for GDA, and would also need to be addressed in Phase 2 by

the licensee. In such cases, the design would need to be sympathetic to the needs of the licensee.

52 In my opinion, the vast majority of the claims that I assessed were appropriate, and all of the arguments that I assessed were adequate (although more areas were assessed for their claims than for their arguments, see Table 2).

53 I have identified no ROs, no RIs or no potential exclusions to date. However, there is the potential for a RO to be raised on optimisation for "jumpers" during Step 4.

54 I conclude that the RP has provided a reasonable safety analysis of radiological protection during normal reactor operation, and that the majority of the claims and all of the arguments assessed to date for radiation doses being ALARP are adequate for GDA Step 3.

3.2 Recommendations

55 I recommend that the UK EPR design proceeds to GDA Step 4 with regard to radiological protection.

4 REFERENCES

1 *UK EPR Pre-Construction Safety Report*. UKEPR-0002-132, Issue 02, EDF and AREVA, June 2009.

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Table 1

Radiological Protection (including Level 3 PSA) – Major Applicable Safety Assessment Principles

SAP Number	SAP Title	TAG	GDA Step	WENRA Reference*	IAEA Reference**
Fundamental Principles					
FP.3	Optimisation of protection	T/AST/004	3 / 4	-	SP5 2.2, 2.4
FP.4	Safety assessment	T/AST/004	3 / 4	-	-
FP.5	Limitation of risk to individuals	T/AST/004 T/AST/038 T/AST/043 T/AST/045	3 / 4	E1.1	SP6 2.2
FP.6	Prevention of accidents	T/AST/004 T/AST/045	3 / 4	E2.1	SP8 2.4 ,2.5, 2.8
FP.7	Emergency preparedness and response	T/AST/004	3 / 4	R1.1	SP9 2.5, 2.8
FP.8	Protection of present and future generations	T/AST/004 T/AST/038	3 / 4	-	SP7 2.2, 2.6 to 2.8
Radiation Protection Principles					
RP.1	Normal operation	T/AST/038	3 / 4	E1.1	2.4, 4.9 to 4.13, 6.99 to 6.106
RP.2	Accident conditions	T/AST/038	3 / 4	E1.1	2.7, 2.8, 4.11 to 4.13
RP.3	Designated areas	T/AST/038	3 / 4	E1.1	6.103
RP.4	Contaminated areas	T/AST/038	3 / 4	E1.1	6.103
RP.5	Decontamination	T/AST/038	3 / 4	E1.1	6.104
RP.6	Shielding	T/AST/002 T/AST/038	3 / 4	E1.1	6.102
Numerical Targets and Legal Limits					
NT.1	Assessment against targets	T/AST/043 T/AST/045	3 / 4	E1.1	-
Target 1	Normal operation – any person on site	T/AST/043	3 / 4	E1.1	-
Target 2	Normal operation – any group on site	T/AST/043	3 / 4	E1.1	-

SAP Number	SAP Title	TAG	GDA Step	WENRA Reference*	IAEA Reference**
Target 3	Normal operation – any person off the site	T/AST/043	3 / 4	E1.1	-
Target 4	Design basis fault sequences – any person	T/AST/045	3 / 4	E1.1	-
Target 5	Individual risk of death from on-site accidents – any person on the site	T/AST/045	3 / 4	E1.1	-
Target 6	Frequency dose targets for any single accident – any person on the site	T/AST/045	3 / 4	E1.1	-
Target 7	Individual risk to people off the site from accidents	T/AST/045	3 / 4	E1.1	-
Target 8	Frequency dose targets for accidents on an individual facility – any person off the site	T/AST/045	3 / 4	E1.1	-
Target 9	Total risk of 100 or more fatalities	T/AST/045	3 / 4	E1.1	-
NT.2	Time at risk	T/AST/005 T/AST/043 T/AST/045	3 / 4	E1.1	-

WENRA Reference* refers to the paragraph numbers in Appendix E or Issue R in WENRA Reactor Safety Reference Levels, Western European Nuclear Regulators' Association Reactor Harmonisation Working Group, 2008 (Ref. 20).

IAEA Reference** refers to the Safety Principles (SP) in IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles, Safety Fundamentals, 2006 (Ref. 21), or to the paragraph numbers in IAEA Safety Standards Series No. NS-R-1, Safety of Nuclear Power Plants: Design, Safety Requirements, 2000 (Ref. 22).

Table 2

Radiological Protection (including Level 3 PSA) – Progress of Assessment Regarding Claims and Arguments for the Principles, Targets and Limits in the Safety Assessment Principles

SAP Number	SAP Title	Assessment of Claims Undertaken	Assessment of Arguments Undertaken
Fundamental Principles			
FP.3	Optimisation of protection	Normal operation: Yes Accident conditions: No	Normal operation: Yes Accident conditions: No
FP.4	Safety assessment	Yes	Yes
FP.5	Limitation of risk to individuals	Yes	Yes
FP.6	Prevention of accidents	No	No
FP.7	Emergency preparedness and response	No	No
FP.8	Protection of present and future generations	Yes	Yes
Radiation Protection Principles			
RP.1	Normal operation	Yes	Yes
RP.2	Accident conditions	No	No
RP.3	Designated areas	Yes	Yes
RP.4	Contaminated areas	Yes	Yes
RP.5	Decontamination	Yes	No
RP.6	Shielding	Yes	No
Numerical Targets and Legal Limits			
NT.1	Assessment against targets	Normal operation: Yes Accident conditions: No	Normal operation: Yes Accident conditions: No
Target 1	Normal operation – any person on site	Yes	Yes
Target 2	Normal operation – any group on site	Yes	Yes
Target 3	Normal operation – any person off the site	Yes	No
Target 4	Design basis fault sequences – any person	No	No
Target 5	Individual risk of death from on-site accidents – any person on the site	No	No
Target 6	Frequency dose targets for any single accident – any person on the site	No	No
Target 7	Individual risk to people off the site from accidents	No	No
Target 8	Frequency dose targets for accidents on an individual facility – any person off the site	No	No

SAP Number	SAP Title	Assessment of Claims Undertaken	Assessment of Arguments Undertaken
Target 9	Total risk of 100 or more fatalities	No	No
NT.2	Time at risk	No	No

Annex 1

Radiological Protection (including Level 3 PSA) – Assessment of Pre-Construction Safety Report (PCSR) against Safety Assessment Principles

A1.1 As Low As Reasonably Practicable (ALARP) During Normal Reactor Operation

A1.1.1 Relevant Fundamental Principles, Radiation Protection Principles, Numerical Targets and Legal Limits

1 The principles of radiological protection are justification, optimisation and limitation, as summarised in Section 2.2. Justification is not regulated by HSE and is not considered in the Safety Assessment Principles (SAP). Optimisation of radiation doses involves restricting exposures to ionising radiation "so far as is reasonably practicable" (SFAIRP) so that doses received are ALARP. Even so, there are limits on the magnitude of the doses that people may receive. Optimisation and limitation cut across many of the fundamental principles, radiation protection principles, and numerical targets and legal limits described in the SAPs (Ref. 4). These principles, targets and limits and the Technical Assessment Guides (TAGs) that are relevant to ALARP during normal reactor operation are listed below.

2 The fundamental principles relevant to normal reactor operation are as follows.

- FP.3 – Optimisation of protection.
- FP.4 – Safety assessment.
- FP.5 – Limitation of risks to individuals.
- FP.8 – Protection of present and future generations.

3 The radiation protection principles relevant to normal reactor operation are as follows.

- RP.1 – Normal operation.
- RP.3 – Designated areas.
- RP.4 – Contaminated areas.
- RP.5 – Decontamination.
- RP.6 – Shielding.

4 The numerical targets and legal limits relevant to normal reactor operation are as follows.

- NT.1 – Assessment against targets.
- Target 1 – Normal operation – any person on the site.
- Target 2 – Normal operation – any group on the site.
- Target 3 – Normal operation – any person off the site.
- NT.2 – Time at risk.

5 The TAGs relevant to normal reactor operation are as follows.

- T/AST/002 – Radiation Shielding (Ref. 23).
- T/AST/004 – Fundamental Principles (Ref. 24).
- T/AST/005 – Demonstration of ALARP (Ref. 25).
- T/AST/038 – Radiological Protection (Ref. 26)
- T/AST/043 - Radiological Analysis – Normal Operation (Ref. 27).

A1.1.2 Legal framework

6 The PCSR (Ref. 1) outlined the legal framework for radiological protection during normal reactor operation in England and Wales in Sub-Chapter 12.0. This legal framework comprised The Ionising Radiations Regulations 1999 (IRR99) (Ref. 7) and The Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000 (RSBSSEWD) (Ref. 9); the latter is enforced by the Environment Agency (EA). The legislation provides the framework for radiological protection in terms of optimisation and limitation (IRR99) (Ref. 7), and for dose constraints for members of the public from nuclear sites.

A1.1.3 Optimisation

7 Regulation 8 of IRR99 (Ref. 7) requires restriction of exposure and includes the importance of the hierarchy of control measures. The importance of this hierarchy is also emphasised in para. 478 of the SAPs (Ref. 4). Regulation 8(1) requires radiation employers to take all necessary steps to restrict SFAIRP the extent to which employees and other persons are exposed to ionising radiation. Regulation 8(2) requires radiation employers, SFAIRP, to restrict exposure to ionising radiation by means of engineering controls and design features (and in addition by the provision and use of safety features and warning devices), and to provide such systems of work as will SFAIRP restrict the exposure to ionising radiation. In addition, where it is reasonably practicable to further restrict exposure by means of personal protective equipment, then such equipment must be provided.

8 T/AST/038 (Ref. 26) expects a safety case for a facility to have a strategy for restricting exposure to ionising radiation, and to show how restriction has been achieved. The strategy should cover all sources of radiation arising from the plant and incorporate all reasonably practicable measures for reducing exposures. NT.1 of the SAPs (Ref. 4) expects a safety case to be assessed against numerical targets and legal limits for, amongst other things, normal operation. These expectations are also encompassed by FP.3 and FP.4 on optimisation of protection and safety assessment, respectively, and in para. 479 of the SAPs (Ref. 4). Since dose optimisation will, by default, also protect present and future generations by minimising doses to people that might affect them and their offspring, these requirements are also encompassed by FP.8 in so far as it relates to radiological protection. Guidance on the fundamental principles is provided in T/AST/004 (Ref. 24).

A1.1.3.1 Sources of Radiation

9 The PCSR (Ref. 1), Sub-Chapter 12.2, identified the sources of radiation in the primary circuit as 33 radionuclides. Realistic source term data were compiled from corrosion product activities (average values from feedback from N4 design Nuclear Power Plants (NPPs)) and fission product activities (conservative values from N4 design NPPs). More conservative data were used to define the biological protection design source term which was used as a design parameter for buildings, systems and shielding provisions (these data were from spectrometric measurements made in N4 design NPPs).

10 The radionuclides in the primary circuit came from: release of fission products from the fuel through clad defects; residual contamination from uranium oxide (from fissile material during preceding campaigns and / or the fuel manufacturing process); activation of corrosion products released into the primary circuit (for example, ^{58}Co and ^{60}Co); and activation of the constituents of the primary coolant itself (for example, ^{3}H and ^{16}N). The Chemical Volume and Control System (CVCS) maintained the primary coolant at pH 7.2 and 300^{o}C, which was reported as being optimum to limit production and transport of corrosion products. This would minimise the quantity of radionuclides entering the

primary coolant from that source. More detailed information on radionuclides from fission products, and from activation of released corrosion products and primary coolant constituents, was provided in supporting documentation (Ref. 28).

11 Another source of radionuclides was from impurities in the spent fuel water and pool heat removal system, and came from: release of fission products from defective fuel; deposition of activated corrosion products on the surface of stored fuel; and transfer of small quantities of primary coolant via the transfer tube during fuel transport operations.

12 In order to reduce the levels of activated corrosion products with the greatest impact on radiological protection, the UK EPR design would have changes in the use of the following materials in contact with the primary coolant.

- A reduction in the use of stellites in hard facings (where ^{59}Co is activated to ^{60}Co), and of inconel 690 alloys and some stainless steels (where ^{58}Ni is activated to ^{58}Co); ^{58}Co and ^{60}Co accounted for over 80% of equivalent dose rates.
- A reduction in the use of helicoflex seals (where ^{109}Ag is activated to ^{110m}Ag).
- An increased use of antimony-free bearings (where ^{123}Sb is activated to ^{124}Sb).

13 Radioactivity would not normally be present in secondary systems, but could result from a leak in a steam generator.

14 Expectations for sources of radiation are covered in SAP RP.1, and further guidance is provided in T/AST/038 (Ref. 26). In my opinion, the claims for radiation sources are appropriate. The arguments that underpinned those claims are reasonable in that the sources were identified systematically and are based on operational data, and fulfilled the expectations in T/AST/038 (Ref. 26). The evidence to substantiate those arguments will be assessed during Step 4.

A1.1.3.2 Restricting Exposure by Design

A1.1.3.2.1 Designated Areas

15 The PCSR (Ref. 1) described a systematic approach to radiological protection in Sub-Chapter 12.3. The parts of the facility that would be designated as controlled areas under IRR99 (Ref. 7) were identified, and were divided into four zones (green, yellow, orange and red) based on dose rates. These four zones were further sub-divided into two or more sub-zones. Zoning also took into account levels of surface and airborne contamination (in particular, gaseous iodine and aerosols from active liquids). This was usually done on the basis of worst-case scenarios for dose uptake due to a possible internal dose (not just on external dose rates or contamination levels), although how this was achieved was not clear. Clarification of this matter will be secured from the RP during Step 4.

16 Expectations for designated areas are encompassed in SAP RP.3, and further guidance is provided in T/AST/038 (Ref. 26). In my opinion, the claims for designated areas are appropriate. The arguments that underpinned those claims are reasonable in that they factored in not only external dose rates and levels of surface and airborne contamination, but also potential internal dose, and fulfilled the expectations in T/AST/038 (Ref. 26). The arguments are also consistent with RP.3 in so far as it related to designated areas. The evidence to substantiate those arguments will be assessed during Step 4.

A1.1.3.2.2 Shielding

17 External dose rates were controlled in part by shielding provisions which were described in Section 2 of Sub-Chapter 12.3 of the PCSR (Ref. 1). These provisions took account of the need for access into the Reactor Building for seven days before shutdown to allow

outage preparations to be undertaken, and three days after restart of the reactor. The description of the shielding provisions included shielding materials, calculation methods, computer codes, and shielding measures for different parts of the NPP.

18 Expectations for shielding are covered in SAP RP.6, and further guidance is provided in T/AST/002 (Ref. 23). In my opinion, the claims for shielding are appropriate. The arguments to underpin those claims were not assessed during Step 3, and will be considered during Step 4 along with evidence to substantiate those arguments.

A1.1.3.2.3 Contaminated Areas

19 A major factor for controlling internal doses from surface and airborne contamination was the ventilation system which was described in Section 3 of Sub-Chapter 12.3 of the PCSR (Ref. 1). The objectives for the ventilation system were outlined for the Fuel Building, Nuclear Auxiliary Building and Safeguard Buildings, namely, to limit radioactive gases and aerosols in the atmosphere, and to ensure that atmospheric contamination did not spread from potentially more contaminated rooms to potentially less contaminated rooms. The ventilation requirements for the Reactor Building were also described. The key design feature for the Reactor Building was that it was built in two compartments: the equipment compartment (which enclosed the primary system elements); and the service space (where access was possible with the reactor at power if wearing basic protective suiting). The ventilation served to prevent radioactive airborne contamination from moving from the equipment compartment into the service space. Section 3 of Sub-Chapter 12.3 also outlined the purging process to allow entry into the equipment compartment for short periods of time. Additional information on the impact of the two-compartment design on the ventilation systems in the Reactor Building and Nuclear Auxiliary Building was provided in supporting documentation (Ref. 29). The two-compartment design of the Reactor Building also served to restrict exposure to external radiation by preventing access to the higher dose rate areas of the plant.

20 Other factors are also important in controlling both external and internal doses from external radiation and surface and airborne contamination. For example, there is the need for appropriate installed and / or portable monitoring devices to measure external dose rates and levels of surface and airborne contamination throughout the NPP, monitoring devices to check for potential contamination of personnel, and washing and changing facilities to minimise spread of contamination. Monitoring of rooms and personnel was covered in Section 4 of Sub-Chapter 12.3, and washing and changing facilities were covered in Section 1. Section 5 of Sub-Chapter 12.3 described the Plant Radiation Monitoring System (PRMS) which had three functions: to contain activity in the steam generators; to ensure containment integrity; and to contain radioactive substances in sensitive zones outside the containment. The operational duties of the PRMS were: for process monitoring (containment barrier surveys); for use in diagnostics during accident conditions; and for monitoring radioactive gaseous and liquid effluents.

21 Expectations for contaminated areas are covered in SAP RP.4, and further guidance is provided in T/AST/038 (Ref. 26). This guidance also discusses the importance of engineering controls over and above supporting systems of work, and lastly personal protective equipment. In my opinion, the claims for contaminated areas are appropriate. The arguments that underpinned those claims are reasonable in that they summarised the roles of the ventilation system, monitoring devices for rooms and personnel, and PRMS, and fulfilled the expectations in RP.4. The evidence to substantiate those arguments will be assessed during Step 4. In particular, the robustness of the design of the ventilation system and PRMS will be undertaken during Step 4 in liaison with assessors in other topic areas.

A1.1.3.2.4 Decontamination

22 Decontamination is an area where the responsibility would be shared between the RP and the licensee in the future. Dedicated decontamination facilities would need to be incorporated into the design as necessary by the RP, and the licensee would manage such facilities in due course. Sub-Chapter 12.3 of the PCSR (Ref. 1) stated that equipment to detect contamination on employees would include hand and foot monitoring equipment, and scanning turnstiles at the Reactor Building exit, between the controlled and supervised areas, and at the site exit. Sub-Chapter 12.3 also noted that areas within the NPP that would require designation as active areas would be identified and supported by adequate changing room facilities. Decontamination provisions for the facility, its plant and equipment, were included in two places in Chapter 12.3 of the PCSR (Ref. 1): as design rules for rooms, where rooms such as the hot workshop or the decontamination room were separated from passageways (in Section 1.4); and as a pump decontamination room in the Fuel Building (in Section 2.7). It was not clear whether the pump decontamination room was the only decontamination facility in the NPP.

23 Expectations for decontamination are covered in SAP RP.5, and further guidance is provided in T/AST/038 (Ref. 26). In my opinion, the claims for decontamination provision are not fully appropriate, in that I would expect more decontamination facilities to be located within the NPP, such as for bringing items out of controlled areas (although monitoring and decontamination of small items may be associated with changerooms). The claims, arguments that underpin those claims, and evidence to substantiate those arguments, will be secured and assessed during Step 4.

A1.1.3.3 Restricting Exposure by Work Activity

A1.1.3.3.1 Optimisation Process for Work Activities

24 The RP's approach to optimising dose uptake for personnel according to work activities was outlined in Sub-Chapter 12.4 of the PCSR (Ref. 1). The approach aimed to: achieve an optimisation approach to radiological protection similar to that applied to safety; include the UK EPR design in an improvement process in relation to the best NPPs operating in France; reduce the dose uptake of the most exposed groups of employees (for particular work activities) with the highest individual or collective doses; and ensure strict compliance with radiological protection standards and criteria whilst allowing employees to enter the Reactor Building during power operation (and thereby improving reactor availability).

25 To meet these aims, the optimisation studies were mainly based on: recent operational feedback; designers being at the centre of the optimisation approach; the project having a collective dose target of 0.35 person-Sv per year per unit averaged over 10 years; and priority being given to the most exposed groups.

26 The method for the detailed EPR dose prediction analysis consisted of: identifying the most exposed groups by reviewing dose uptake statistics from the best operating 1300 MWe NPPs; selecting high priority activities with high dose uptakes during outages; predicting dose uptakes depending on the type of outage; and deriving a predicted annual collective dose over a 10-year cycle.

27 The optimised dose was established by first optimising the source term and dose rate, and involved the following.

- Removing stellite from vessels' internals and valves in contact with the primary coolant.
- Pressuriser developments (this involved: installing a floor separating the spray and discharge systems at the pressuriser-dome level to reduce dose rates in the safety

valves area; monitoring nominal pressure remotely via a special pressurised line; and removing the expansion line / pressuriser nozzle thermal sleeve to avoid dead zones).

- Installation optimisation (this involved: separate routing of the CVCS pipework from the valves and pumps; residual heat removal system operation provided by the safety injection system in the Safeguard and Electrical Buildings; and inclusion of a shielded storage area for the pressure vessel head in the Reactor Building).
- Measures to remove "hot spots" in the design (this involved: elimination of socket welds on pipework carrying radioactive fluids; chemistry optimisation; and reduction of the amount of chromium and antimony in the primary pumps).

28 Optimising the work where radiation doses would be incurred also had to be balanced with design choices, some of which were a challenge to radiological protection (such as entering the Reactor Building with the reactor at power) and some of which provided benefits (such as increase in primary and secondary manway diameters to facilitate access, or installation of permanent shielding around particular equipment). Further details were provided in Section 2.3.1.2 of Sub-Chapter 12.4 of the PCSR (Ref. 1).

29 Expectations for adequate protection against exposure to radiation and radioactive substances during normal operation are covered in SAP RP.1, and further guidance is provided in T/AST/038 (Ref. 26). Optimisation is also encompassed in FP.3. In particular, T/AST/038 (Ref. 26) expects a safety case for a facility to have a strategy for restricting exposure to ionising radiation and to show how restriction has been achieved. In my opinion, the claims for the optimisation process for work activities are appropriate. The arguments that underpinned those claims are reasonable in that there was a systematic process that balanced optimising the source term and dose rate against design choices (which could present challenges or benefits to radiological protection). The evidence to substantiate those arguments will be assessed during Step 4.

A1.1.3.3.2 Optimisation of High Dose Work Activities

30 The process for prioritising work activities was described in detail in supporting documentation (Ref. 30). The work activities were identified as HIGH, SIGNIFICANT or LOW with regard to dose uptake. There were seven work activities that contributed to approximately 50% of the total dose and these were classed as HIGH. The remaining 50% consisted of seven work activities classed as SIGNIFICANT and 11 work activities classed as LOW. The seven work activities classed as HIGH were given priority for dose optimisation. Dose optimisation for the other two classes of work activity would be carried out over longer timescales.

31 The methodology for the optimisation studies for the seven priority work activities (contributing to 50% of the dose) involved a structured series of meetings and discussions, and was described in supporting documentation (Ref. 31). A summary of the findings of the optimisation studies were presented in Sub-Chapter 12.4 of the PCSR (Ref. 1) which outlined the work involved, discussed some of the key improvements leading to dose reduction, and summarised the predicted doses in terms of Initial Predicted Dose Estimate (EDPI) or Optimised Predicted Dose Estimate (EDPO) (see Section 2.1.5 above). Details of the development of the dose estimates were presented in supporting documentation as follows.

- Thermal insulation operations (Ref. 32).
- Worksite logistics (Ref. 33).
- Valve activities (Ref. 34).
- Steam generator worksite (Ref. 35; Ref. 36; Ref. 37).

- Worksite for opening and closing the reactor vessel (Ref. 38).
- Fuel posting out worksite (Ref. 39).
- Waste treatment operations (Ref. 40).

32 The EDPI and EDPO values for a particular work activity in the PCSR (Ref. 1) were different from those in the supporting documentation. The reason for this was that the values in the supporting documentation gave results for the first step of the optimisation process, and the values in the PCSR were from the second step. The values in the first step assumed a 10% reduction in source term, and those in the second step assumed a 15% reduction due to removal of stellite from key parts of the design. The third step of the process was ongoing where further improvements in optimisation were planned.

33 Expectations for adequate protection against exposure to radiation and radioactive substances during normal operation are covered in SAP RP.1, and further guidance is provided in T/AST/038 (Ref. 26). Optimisation is also encompassed in SAP FP.3. In my opinion, the claims for radiological protection for work activities resulting in the highest doses under normal operation are appropriate. The arguments that underpinned those claims are reasonable in that there was a step-wise and systematic process that identified work activities from the highest to the lowest dose burdens, and which dealt with them in a prioritised manner. The optimisation work for all these work activities was still ongoing, with higher dose activities being dealt with as a matter or priority. This is as I would expect at this stage in the design process, and fulfilled the expectations of RP.1 and were consistent with FP.3 in so far as it relates to radiological protection for particular work activities. The evidence to substantiate those arguments will be assessed during Step 4, including the robustness of the dose estimates, evidence to support the percentage dose reductions assumed for the various stages of the assessments, and reconciliation of the EDPIs and EDPOs in the PCSR and supporting documentation.

A1.1.3.3.3 Time at Risk

34 The discussion of the steam generator worksite in Sub-Chapter 12.4 of the PCSR (Ref. 1) explained that the highest dose work activities were those requiring person-entry in the channel head to install nozzle dams, humidity detectors, etc. In these cases “jumpers” were used whose exposure time was measured in seconds. No dedicated dose estimates had been made for “jumpers”. However, the optimisation of work activities at the steam generator worksite may also impact on doses to “jumpers” in terms of planned improvements by reducing the source term and reducing exposure time (e.g. by increasing diameters of manways) (Ref. 35).

35 Expectations for time at risk are covered in SAP NT.2 where there should be sufficient control of radiological hazards at all times. Guidance is provided in the SAPs (Ref. 4) and in T/AST/005 (Ref. 25), and is geared mainly towards time at risk of the plant. For radiological protection, however, time at risk relates to time of exposure of the individual, and guidance is provided on dose / risk sharing (Refs 12 and 25). No claims or arguments were presented in the PCSR or supporting documents for NT.2 as it related to “jumpers”. The claims, arguments that underpin those claims, and evidence to substantiate those arguments, will be secured and assessed during Step 4.

36 In my opinion, in the unlikely event that the work activity carried out by “jumpers” could not be undertaken by any other means, then this matter may develop into a Regulatory Observation during Step 4 since control of exposure in timeframes measured in seconds is difficult to manage and the application of the ALARP principle is difficult to demonstrate.

A1.1.4 Limitation

A1.1.4.1 Framework for dose limits and constraints

37 Dose limits are specified in regulation 11 and Schedule 4 of IRR99 (Ref. 7), where every employer shall ensure that employees and other persons are not exposed to ionising radiation to an extent that any dose limits specified in Part I of Schedule 4 are exceeded in any calendar year. SAP FP.5 expects limitation of risks to individuals such that measures for controlling radiation risks should ensure that no individual bears an unacceptable risk of harm. This is achieved in part through regulation 11 of IRR99 (Ref. 7) for radiological protection.

38 A safety case should be assessed against numerical targets and legal limits for, amongst other things, normal operation (NT.1). The SAPs (Ref. 4) provide targets for any person or group of people on the site, and for any person off the site (Targets 1, 2 and 3, respectively). These are presented as Basic Safety Limits (BSLs) (levels above which the risk is unacceptable) and Basic Safety Objectives (BSOs) (levels below which the risk is broadly acceptable). New facilities or activities should at least meet the BSLs, but application of ALARP may drive risks lower. To make best use of ND's resources, its policy is not to seek further improvements below the BSO, although the ALARP principle still applies to dutyholders below the BSO. The BSLs for employees working with ionising radiation, other employees on the site, and any person off the site, are 20 mSv, 2 mSv, and 1 mSv, respectively. The BSL for average effective dose for a defined group of employees is 10 mSv (this is an annual average dose for a group of employees involved in a specific task). The BSLs for employees working with ionising radiation (NT.1 Target 1) and for people off the site (NT.1 Target 3) are also dose limits under IRR99, regulation 11 (Ref. 7). Additional guidance on numerical analysis under normal operation for Targets 1, 2 and 3 is provided in T/AST/043 (Ref. 27).

39 Regulation 8(3) of IRR99 (Ref. 7) requires the use of dose constraints to restrict exposure to ionising radiation at the planning stage where it is appropriate to do so. Additional information in the form of an Approved Code Of Practice (ACOP) and guidance is also available (Ref. 12). Para. 590 of the SAPs (Ref. 4) refers to para. 134 in the guidance to regulation 8(3) of IRR99 (Ref. 12), which advises that the dose to members of the public from each source should be constrained to 0.3 mSv per year. Para. 590 of the SAPs also advises that HSE's view is that a single source should be interpreted as a site under a single dutyholder's control, since this is an entity for which radiological protection can be optimised as a whole. Subsequent to this, the Health Protection Agency Radiation Protection Division (HPA RPD) issued recommendations that doses to members of the public from new NPPs should be constrained to 0.15 mSv per year (Ref. 17).

A1.1.4.2 Dose limits and constraints for employees

40 The PCSR (Ref. 1), Sub-Chapter 12.0, stated that the UK EPR design complied with the dose limits in IRR99 (Ref. 7), including dose limits for employees. The PCSR (Ref. 1), Sub-Chapter 12.4, stated that the reference dose for employees for the UK EPR design was based on: the best up-to-date dose statistics from the recent French P4 and N4 NPPs (Ref. 41); an assumed 18-month fuel cycle; and an outage cycle that consisted of two refuelling only outages, three normal refuelling outages (involving partial inspection), plus one 10-year in-service inspection outage during the 10-year cycle. The reference dose for those units was calculated as 0.448 person-Sv per year per unit averaged over 10 years. The collective dose for the best operating unit of the French fleet was 0.440 person-Sv per year per unit averaged over 10 years, and as this was close to the calculated reference dose, the collective dose for the best operating unit (0.440 person-Sv per year per unit averaged over 10 years) was chosen as the reference dose. The collective dose target for employees for the UK EPR design (presented in Sub-Chapter 12.1) was 0.35 person-Sv per year per unit averaged over 10 years, which was based on the reference dose

(0.440 person-Sv per year per unit averaged over 10 years) and took account of planned improvements for the UK EPR design. The robustness of the collective dose target will be assessed during Step 4.

41 Averaging the collective dose over 10 years will provide over-estimates of potential doses during years with no outages, and under-estimates of potential doses during years with outages. The greatest under-estimate will be attributed to the year with the outage with the highest dose burden (10-year in-service inspection). Nevertheless, in my opinion, this is an appropriate way to average doses for planning purposes in that it takes account of all the types of outages that take place. It is important, therefore, that collective doses for different types of outages are considered for a particular year. The evidence to underpin the collective dose per outage type per work activity will be assessed during Step 4.

42 The EDPIs and EDPOs for the seven work activities that were responsible for 50% of the collective dose were also expressed in terms of collective dose (see Section A1.1.3.3.2 above). The UK EPR design Safety Design Objectives fixed the individual limit for an employee at 10 mSv over 12 consecutive months (this was a company dose limit). This Safety Design Objective met the BSL for employees working with ionising radiation in NT.1 Target 1. The optimisation studies for work activities identified to date represented dose estimates as collective doses, so it was not possible at this stage to confirm whether these estimated doses would meet the target for average effective dose in a calendar year to defined groups of employees working with ionising radiation (10 mSv in NT.1 Target 2; the average annual dose for a group of employees involved in a specific task). I would expect the estimated doses for these work activities to meet this target in a modern NPP; this will need to be confirmed during Step 4.

43 Limitation of risks to individuals is encompassed in SAP FP.5. The need for a safety case to be assessed against numerical targets and legal limits is covered in NT.1. Expectations for dose targets and requirements for legal limits from normal operation for employees on the site are covered in Targets 1 and 2, and for any person off the site (including members of the public) in Target 3 (public doses are considered in Section A1.1.4.3 below). Further guidance is provided in T/AST/043 (Ref. 27). In my opinion, the claims for numerical targets and legal limits are appropriate for Targets 1 and 2. The arguments that underpinned those claims are reasonable in that there was a step-wise and systematic process to deal with those targets and limits. The optimisation work for work activities was still ongoing, so it was only to be expected that average effective doses for individuals in groups of employees involved in specific tasks on the site were not yet available to compare with Target 2. As indicated above, I expect this target to be met in due course. The evidence to substantiate those arguments will be assessed during Step 4.

A1.1.4.3 Dose limits and constraints for the public

44 The PCSR (Ref. 1), Sub-Chapter 12.0, stated that the UK EPR design complied with the dose limits in IRR99 (Ref. 7), including doses to other persons (including members of the public). It also stated that it complied with the requirements for maximum doses to individuals which may result from a defined source for use at the planning stage in radiation protection in RSBSSEWD (Ref. 9) (regulated by EA). The maximum doses in RSBSSEWD (Ref. 9) are 0.3 mSv from any source from which radioactive discharges are made, or 0.5 mSv per year from discharges from any single site. The dose constraints to members of the public in the PCSR (Ref. 1) reflected the maximum doses in RSBSSEWD (Ref. 9) and were below the BSL and legal limit in NT.1 Target 3. These dose constraints met the advice in para. 590 of the SAPs for a single unit, but not if the single source was interpreted as a site under a single dutyholder's control which contained more than one unit (Ref. 4). In addition, the dose constraints did not meet HPA RPD's more recent

recommendations that doses to members of the public from new NPPs should be constrained to 0.15 mSv per year (Ref. 17).

45 Although dose constraints were presented in Chapter 12 of the PCSR (Ref. 1), no estimated doses to members of the public during normal operation were presented in this Chapter. Instead, these estimated doses were presented in Chapter 11 of the PCER (Ref. 18), where the highest dose to a member of the public during normal operation was 25.8 microSv per year, which comprised 21 microSv per year from discharges and 4.8 microSv from direct radiation originating from within the site boundary. These estimated doses were well below the BSL and a little above the BSO in NT.1 Target 3, and were also well below the maximum doses in RSBSSEWD (Ref. 9) and HPA RPD's recent recommendations on public radiation exposure (Ref. 17). The PCER (Ref. 18) noted that exposure to direct radiation would be negligible from the Reactor Building and greatest from radioactive waste stores. The methodology for estimation of direct radiation will be assessed during Step 4. In my opinion, the claims for public exposure from direct radiation originating from within the site boundary during normal operation are appropriate. The arguments that underpin those claims, and evidence to substantiate those arguments, will be secured and assessed for estimated doses to the public resulting from direct radiation originating from within the site boundary during Step 4. I will carry out my assessment in liaison with assessors in EA who lead on discharges of radioactive waste into the environment during normal operation.

A1.2 ALARP During Accident Conditions

A1.2.1 Relevant Fundamental Principles, Radiation Protection Principles, Numerical Targets and Legal Limits

46 Optimisation of radiation doses applies during accident conditions. Dose limits in IRR99 (Ref. 7) do not apply to intervention during radiation emergencies (see regulation 15 of The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR), Ref. 8). Nevertheless, radiation doses should be ALARP, and there are dose levels which should not be exceeded by people on the site (Ref. 42) or by intervention personnel (Ref. 14). In addition, there are emergency reference levels and countermeasures which should be implemented to avert doses to people off the site (Refs 43 and 44). The fundamental principles, radiation protection principles and numerical targets that are relevant to ALARP during accident conditions are described in the SAPs (Ref. 4) and are listed below.

47 The fundamental principles relevant to accident conditions are as follows.

- FP.3 – Optimisation of protection.
- FP.6 – Prevention of accidents.
- FP.7 – Emergency preparedness and response.

48 The radiation protection principle relevant to accident conditions is as follows.

- RP.2 – Accident conditions.

49 The numerical targets and legal limits relevant to normal reactor operation are as follows.

- NT.1 – Assessment against targets.
- Target 4 – Design basis fault sequences – any person.
- Target 5 – Individual risk of death from on-site accidents - any person on the site.
- Target 6 – Frequency dose targets for any single accident – any person on the site.
- Target 7 – Individual risk to people off the site from accidents.

- Target 8 – Frequency dose targets for accidents on an individual facility – any person off the site.
- Target 9 – Total risk of 100 or more fatalities.

50 The TAG relevant to accident conditions is as follows.

- T/AST/045 - Radiological Analysis – Fault Conditions (Ref. 45).

A1.2.2 Legal Framework

51 The PCSR (Ref. 1) outlined the legal framework for radiological protection during accident conditions in Sub-Chapters 12.0 and 12.5. This legal framework comprised IRR99 (Ref. 7) and REPPIR (Ref. 8). Information, instruction and training, and dosimetry for accidents, were dealt with in regulations 14 and 23 of IRR99 (Ref. 7), respectively; HSE guidance is available (Ref. 12). Emergency exposures, including information, instruction and training for intervention personnel, were dealt with in regulation 14 of REPPIR (Ref. 8); HSE guidance is available (Ref. 13). Sub-Chapter 12.5 also summarised the upper dose levels for emergency exposures for implementing emergency plans as advised in HSE's internal guidance on dose levels for emergencies (Ref. 14). These contributed to NT.1 of the SAPs (Ref. 4) in that safety cases should be assessed against numerical targets and legal limits for, amongst other things, design basis faults and radiological accident risks to people on and off the site.

A1.2.3 Post Accident Accessibility

52 The PCSR (Ref. 1), Sub-Chapter 12.5, also identified areas where access would be required in the long term (over a period of one year) following an accident. These areas were based on the following criteria: systems that would be absolutely necessary for use in the long term (i.e. systems used to maintain the plant in a steady state after an accident and to maintain cooling of the spent fuel pool); systems which would require repair during the post-accident phase; intervention that would be required under the most unfavourable conditions (both in events with no core melt and with core melt accidents); and operations that would have to be carried out before access in order to prepare for repairs.

53 Radiological consequence assessment elements of Level 3 Probabilistic Safety Analysis (PSA) relate to plume dispersion modelling and dose consequences for members of the public. These aspects were not covered in Sub-Chapter 12.5 of the PCSR (Ref. 1).

A1.2.4 Radiological Protection and its implication for the Level 3 PSA

54 Radiological protection under accident conditions and radiological consequence assessment elements of Level 3 PSA were not assessed during Step 3.

- I will consider inclusion of SAP FP.3, FP.6 and FP.7 as they relate to radiological protection during accident conditions in the plan for radiological protection (inc. Level 3 PSA) for Step 4.
- I will include SAP RP.2 in the plan for radiological protection (inc. Level 3 PSA) for Step 4.
- I will include NT.1 as it applies to design basis faults and radiological accident risks to people in the plan for radiological protection (inc. Level 3 PSA) for Step 4.
- NT.1 Targets 5 and 6 deal with impacts of accidents to people on the site. I will consider inclusion of these targets in the plan for radiological protection (inc. Level 3 PSA) for Step 4.

- NT.1 Targets 4 and 9 deal with impacts of accidents to people on and off the site. I will consider inclusion of Targets 4 and 9 as they relate to people on the site in the PID for radiological protection (inc. the Level 3 PSA) for Step 4. I will include Targets 4 and 9 as they relate to people off the site in this plan for Step 4.
- NT.1 Targets 7 and 8 deal with impacts of accidents to people off the site. I will include these targets in the plan for radiological protection (inc. Level 3 PSA) for Step 4.

55 I will work in liaison with assessors in other topic areas in my consideration of NT.1 Targets 4 to 9, and will contribute to the radiological consequence assessment elements of Level 3 PSA which relate to plume dispersion modelling and dose consequences for members of the public, where appropriate.