

**NUCLEAR DIRECTORATE  
GENERIC DESIGN ASSESSMENT – NEW CIVIL REACTOR BUILD**

**STEP 3 RADIOLOGICAL PROTECTION ASSESSMENT OF THE WESTINGHOUSE AP1000  
DIVISION 6 ASSESSMENT REPORT NO. AR 09/020-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 Westinghouse AP1000 Pre-Construction Safety Report (PCSR) undertaken as part of Step 3 of the HSE Generic Design Assessment (GDA) process.

No radiological protection assessment of the Westinghouse AP1000 design was carried out during GDA Step 2, and began well after most other technical areas for Step 3. Therefore, radiological protection has been assessed 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 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. The bulk of the radiological protection assessment work, and the associated Level 3 Probabilistic Safety Analysis (PSA) assessment work, will be carried out during GDA Step 4.

### Scope of assessment carried out

Chapter 13 of the PCSR, together with supporting documentation covered principles and criteria, key radiological protection issues, radiation sources, design features for radiation protection, radiation monitoring, and radiation protection programme. Some areas of work were still ongoing by the Requesting Party (RP), for example, to further refine dose uptake optimisation, but these areas were clearly identified.

The strategy for this assessment area was detailed in the Project Initiation Document (PID). In summary this was to consider: occupational doses during normal operation, including outages and maintenance work; doses to members of the public during normal operation due to direct radiation; and occupational doses and doses to members of the public during accident conditions. 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 GDA Step 4.

Key standards and criteria used for the assessment were the Ionising Radiations Regulations 1999, the Radiation (Emergency Preparedness and Public Information) Regulations 2001, and HSE's Safety Assessment Principles (SAPs), supported by relevant ND Technical Assessment Guides (TAGs).

I focused on occupational radiation exposure during normal reactor operation, such as electricity generation, maintenance and planned activities (e.g. refuelling), and in particular whether exposure to radiation was As Low As Reasonably Practicable (ALARP). During my assessment I raised a number of Technical Queries on matters requiring clarification, or further information, particularly on ALARP. Areas deferred to GDA Step 4 include radiation exposure associated with the fuel route, and occupational and public radiation exposure during accident conditions. Step 4 assessment will require close liaison with other assessment areas, particularly human factors, probabilistic safety assessment, fault studies, mechanical engineering, reactor chemistry, radioactive waste management and decommissioning.

### Conclusions

I conclude that the RP has provided a reasonable safety analysis in the radiological protection topic area during normal operations for the principal plant, and that the claims and arguments are adequate for GDA Step 3. I will further assess the robustness of ALARP arguments based on the detailed evidence to be provided by the RP during Step 4; I will also assess the RP's arguments and evidence for occupational and public radiation exposure during accident conditions. At this time no Regulatory Observations (ROs) or Regulatory Issues (RIs) have been raised, or potential exclusions identified. Overall, I see no reason why, on radiation protection grounds, the Westinghouse AP1000 design should not proceed to Step 4 of the GDA process.

**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 Level
BSL(LL)	Basic Safety Level (Legal Limit)
BSO	Basic Safety Objective
DCD	Design Control Document
EA	The Environment Agency
GDA	Generic Design Assessment
HPA	Health Protection Agency
HPA-RPD	Health Protection Agency – Radiation Protection Division
HSE	The Health and Safety Executive
HSWA74	Health and Safety at Work etc. Act 1974
IRR99	Ionising Radiations Regulations 1999
IAEA	The International Atomic Energy Agency
ND	The (HSE) Nuclear Directorate
NPP	Nuclear Power Plant
PCSR	Pre-construction Safety Report
PID	Project Initiation Document
PSA	Probabilistic Safety Analysis
TAG	(Nuclear Directorate) Technical Assessment Guide
TQ	Technical Query
RCA	Radiologically Controlled Area
RI	Regulatory Issue
RIA	Regulatory Issue Action
RO	Regulatory Observation
ROA	Regulatory Observation Action
RP	Requesting Party
SFAIRP	So Far As Is Reasonable Practicable
SAP	Safety Assessment Principle
SSC	System, Structure and Component
TSC	Technical Support Contractor
WEC	Westinghouse Electric Company LLC
WENRA	The Western European Nuclear Regulators' Association

## TABLE OF CONTENTS

1	INTRODUCTION.....	1
2	NUCLEAR DIRECTORATE'S ASSESSMENT .....	1
	2.1 Requesting Party's Safety Case.....	1
	2.1.1 Radiation Protection Principles and Criteria .....	2
	2.1.2 Radiation Protection during Normal Operation.....	2
	2.1.3 Radiological Protection during Post-Accident Conditions.....	2
	2.1.4 Radiological Access Areas and Work in Contaminated Areas .....	2
	2.1.5 Radiation Sources .....	2
	2.1.6 ALARP Principle .....	2
	2.2 Standards and Criteria .....	3
	2.3 Nuclear Directorate Assessment.....	4
	2.3.1 Assessment Strategy.....	4
	2.3.2 Scope of Assessment.....	5
	2.3.3 Summary of Assessment.....	5
	2.3.4 Progress against PID.....	5
	2.3.5 Follow-up of Issues from Step 2 .....	6
	2.3.6 Step 3 Requirements in HSE GDA Guidance .....	6
	2.3.7 Overseas Regulator Information.....	6
	2.3.8 ALARP Considerations.....	6
	2.3.9 Plans for Step 4 Assessment .....	6
	2.3.10 Research .....	7
	2.3.11 Regulatory Observations and Regulatory Issues .....	7
	2.3.12 Potential Exclusions .....	7
3	CONCLUSIONS AND RECOMMENDATIONS.....	7
	3.1 Conclusions.....	7
	3.2 Recommendations .....	7
4	REFERENCES.....	8

Table 1: Radiological Protection (including Level 3 PSA) – Major Applicable Safety Assessment Principles

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

Annex 1: Assessment of AP1000 PCSR and Supporting Documentation against Standards and Criteria

Annex 2: Radiological Protection (including Level 3 PSA) – Status of Regulatory Issues and Observations

## 1 INTRODUCTION

- 1 ND's GDA process calls for a step-wise assessment of the Requesting Party's (RP) safety submission. Steps 2, 3 and 4 deal with claims, arguments and evidence, respectively.
- 2 My report presents the findings of the radiological protection and Level 3 PSA assessment of the Westinghouse AP1000 Pre-Construction Safety Report (PCSR) (Ref. 1) 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. 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 the Nuclear Directorate (ND) and explains the process associated with sampling of safety case documentation. The Safety Assessment Principles (SAP) (Ref. 4) have been used as the basis for the assessment of radiological protection and Level 3 Probabilistic Safety Analysis (PSA), 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) (Refs 5 to 9) have also been used to inform the process of assessment 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 Westinghouse AP1000 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 PSA assessment will, therefore, be carried out during Step 4.
- 4 I have focused on occupational radiation exposure during normal reactor operations, such as electricity generation, maintenance and planned activities (e.g. refuelling). Areas I have identified to consider during Step 4, include occupational radiation exposure associated with the fuel route and waste handling, shielding, ventilation, contamination control and radiological monitoring systems, and occupational and public radiation exposures during fault and accident conditions.
- 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 is addressed principally in Chapter 13 of the PCSR. The topic areas were key radiological protection issues, radiation sources, design features for radiation protection, radiation monitoring, and radiation protection programme. However, the level of detail within the PCSR was limited and much of the information I needed in order to perform my assessment was in the Design Control Document (DCD), (Ref. 10), in particular in Chapter 12.

### 2.1.1 Radiation Protection Principles and Criteria

7 The RP asserts that As Low As Reasonably Practicable (ALARP) policy is applied at all design stages, and for all design aspects, of the AP1000, and that exposure time, distance, shielding and source reduction are fundamental considerations in the design. The radiation protection principles and criteria adopted are largely those in ND's SAPs and the Ionising Radiation Regulations (IRR99), (Ref. 11). In addition the RP has set an occupational collective dose design target of 1 person Sievert per year.

### 2.1.2 Radiation Protection during Normal Operation

8 Minimisation of occupational radiation exposure is achieved through: core and fuel design, and choice of materials so as to minimise fundamental radiation sources; operational chemistry, which maximises fuel performance; purification systems; shielding; automation; and overall simplification of the plant. The assessed occupational radiation exposure has recently been updated to reflect improvements in materials and operational chemistry and is given in Ref. 12. This gives the total projected occupational radiation exposure as 0.22 person Sievert per year (not 0.67 as given in the PCSR and DCD). This includes normal operations, refuelling operations, and routine maintenance.

### 2.1.3 Radiological Protection during Post-Accident Conditions

9 Radiation protection during post-accident conditions is viewed by the RP as a fundamental design consideration. Methods incorporated to minimise radiation exposure to workers include shielding, automation, and overall design approach of the plant. The safety systems are located inside the containment and shield building, and post-accident fluid is not re-circulated outside containment, limiting the extent to which post-accident contamination would be spread compared to traditional PWR designs. Similarly the need for operator actions post-accident has been greatly reduced.

### 2.1.4 Radiological Access Areas and Work in Contaminated Areas

10 Minimisation of contamination is addressed in the design, and access control and personnel movements are considered in plant layout to reduce the potential for spread of contamination. The design layout gives plant areas categorised into radiation zones according to the design basis radiation levels and anticipated personnel occupancy. Handling of contaminated items is addressed.

### 2.1.5 Radiation Sources

11 A comprehensive treatment of radiation sources is given, including a tabular description of the sources of radiation from the reactor plant (operating and shutdown), the exposure pathways and how they are managed.

### 2.1.6 ALARP Principle

12 To maintain in-plant radiation exposures ALARP attention has been paid to minimising the necessity for access to, and personnel time spent in, radiation areas, and to minimising radiation levels in routinely occupied plant areas in the vicinity of plant equipment expected to require personnel attention. Particular attention has been paid in design to:

- reliability and maintainability, to reduce the maintenance requirements on radioactive components;

- design of structures, systems and components to reduce the radiation fields, to allow operation, maintenance and inspection activities to be performed with minimum exposure;
- reduce access and repair and removal times, thereby effectively reducing the time spent in radiation fields during operation, maintenance, and inspection;
- utilise remote and semi-remote operation, maintenance and inspection.

13 Areas addressed were, normal operation, maintenance and repairs, refuelling operations and fuel storage, in-service inspection and calibrations, radioactive waste handling and disposal, other anticipated operational occurrences, and decommissioning.

## 2.2 Standards and Criteria

14 The Project Initiation Document (PID), (Ref. 13) for radiological protection for Step 3 identifies the principles that are of greatest relevance to radiological protection in the SAPs, and provides references to TAGs that support those principles. In addition, the document tracks the SAPs against reference levels and fundamental principles in documentation provided by The Western European Nuclear Regulators' Association (WENRA) (Ref. 14) and The International Atomic Energy Agency (IAEA) (Refs 15 to 16), respectively.

15 The system underlying all of the standards and criteria above is that exposure to ionising radiation requires justification, optimisation and limitation. Justification is not a matter for this assessment as it is not regulated by HSE and is not considered in the SAPs. Compliance with dose limits for either workers or members of the public during normal operation clearly should not be an issue for modern nuclear plant in normal operation (as indeed is the case; see later in this report). Hence the key basis against which assessment is carried out is that exposures must be ALARP. In this report the UK term ALARP is taken to be synonymous with both the international term ALARA (As Low As Reasonably Achievable), and the wording of IRR99 that exposures must be restricted So Far As Is Reasonably Practicable (SFAIRP). The principal standards and criteria against which to judge whether this requirement has been met are the HSE Approved Code of Practice (ACOP) and Guidance for IRR99 HSE publication L121, (Ref. 17), supplemented by further guidance published on the HSE website and in TAGs. Most importantly, IRR99 requires a hierarchical approach. Control of exposure should firstly be achieved by engineered means and design features, and in addition by provision of safety features and warning devices. Only after these have been applied should consideration be given to the use of supporting systems of work. Lastly, personal protective equipment should be provided to further restrict exposure where this is reasonably practicable.

16 In the SAPs, the fundamental principles that have some relevance to radiological protection are FP.3 to FP.8. The radiation protection principles (RP.1 to RP.6), all the numerical targets and legal limits (NT.1 including Targets 1 to 9, and NT.2) are relevant. I address some of these principles, targets and limits during Step 3, but some will be dealt with during Step 4.

17 The PID also identified other principles in the SAPs that had some relevance to radiological protection but were not key areas (for example integrity of metal components and structures). These will be considered as appropriate during Step 4.

18 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. 18), refer to risks, as do the expectations in many of the SAPs (Ref. 4). The duties of radiation employers in IRR99 and expectations in some of the SAPs, however, refer to radiation exposures and not just to the implied risk. The



hierarchy of risk in IRR99 (Ref. 11) 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. 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.

- 19 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.
- 20 Section 6, of HSWA74 (Ref. 18) places general duties on manufacturers etc. as regards articles and substances for use at work, and applies to any person who designs, manufactures, imports or supplies any article for use at work. Where that work is with ionising radiation, the duty is extended to apply to articles for use at work by IRR99, Regulation 31. This requires manufactures 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. Hence the requirement in law to keep radiation exposures ALARP applies not only to the operator of a nuclear power station, but also, for example, to Westinghouse Electric Company were it the designer.
- 21 IRR99 Regulation 8(3) requires the use of dose constraints to restrict exposure at the planning stage where it is appropriate to do so. The guidance to IRR99 (Ref. 17) 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 Target 3. However HPA - RPD has recently recommended that doses to members of the public from new nuclear power plants should be constrained to 0.15 mSv per year (Ref. 19).

## **2.3 Nuclear Directorate Assessment**

### **2.3.1 Assessment Strategy**

- 22 My assessment strategy was outlined in the PID (Ref. 13). 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.
- 23 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 Probabilistic Safety Analysis (PSA), deterministic safety analysis (fault studies), reactor chemistry, radioactive waste management, decommissioning, mechanical engineering, human factors, public exposures, and control and instrumentation.
- 24 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).

25 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

26 My assessment concentrated on occupational 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 (outside of the scope of the GDA process), optimisation and limitation, had been applied. My main focus was on optimisation and to assess whether exposure to radiation was ALARP.

27 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 for accident conditions will be undertaken during Step 4.

### 2.3.3 Summary of Assessment

28 My assessment is set out in detail in Annex 1.

29 The key areas that I considered were:

- Routine occupational radiation exposure.
- Further radiological protection plant design features.
- Routine public exposure.

30 I conclude (Annex 1 Section A2) that the RP's approach to routine occupational radiation exposure, and in particular with the requirements for ALARP, is consistent with the required standards and criteria, and commensurate with the UK approach and hierarchy of control measures. The arguments given in the submission and ancillary information to support the claims made are sufficiently robust for the purposes of Step 3 GDA assessed against relevant SAPs (see Table 1).

31 With regard to the further radiological protection plant design features I conclude (Annex 1 Section A3) that, for the purposes of step 3 GDA appropriate attention has been given to the designation of areas, contamination control and decontamination. I judge that the RP has provided adequate arguments against SAPs RP.3 to RP.5.

32 For routine public exposure from direct radiation I conclude, (Annex 1 Section A4), that the RP's claims and arguments are adequate for step 3 measured against the relevant criteria and standards. In Step 4 I shall be expecting evidence to support those claims and arguments; the RP's assertion that this "...should be addressed as part of the site selection phase" is not appropriate (see Annex 1 Section A4.2).

### 2.3.4 Progress against PID

33 The PID (Ref. 13) 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 (FP.3 to FP.8), the radiation protection principles (RP.1 to RP.6), 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

34 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

35 The requirements for the RP in Step 3 are set out in paras 3.1 to 3.13 of the GDA guidance (Ref. 20). 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).

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

- Para. 3.14 (on AP1000 design meeting the RP's design safety criteria) is covered 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 2.3.4 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.

37 Para. 3.23 (on the overall design being balanced to the overall risk) is covered in Annex 1 in so far as it applies to radiological protection.

### 2.3.7 Overseas Regulator Information

38 I have not used overseas regulator information in my assessment; this is planned for Step 4.

### 2.3.8 ALARP Considerations

39 The bulk of my assessment dealt with considering whether the ALARP principle had been applied to occupational doses during normal reactor operation and my conclusions are given in Section 2.3.3 above. Other assessors have looked at accident risk, and I will be contributing to the analysis of the Level 3 PSA with regard to plume dispersion modelling and dose consequences during Step 4.

### 2.3.9 Plans for Step 4 Assessment

40 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. In

addition, I will focus on areas not covered in Step 3, such as occupational exposure associated with the fuel route, waste handling, shielding, ventilation, contamination control and instrumentation. I will also assess occupational and public radiation exposure during accident conditions.

- 41 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**

- 42 A research project has been commissioned with a Technical Support Contractor (TSC), covering radiological protection, reactor chemistry and radioactive waste management, 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. I will use the findings of this review to inform parts of my assessment during Step 4.

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

### **2.3.11 Regulatory Observations and Regulatory Issues**

- 44 I have not identified any Regulatory Observations (ROs) or Regulatory Issues (RIs) during my assessment.

### **2.3.12 Potential Exclusions**

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

## **3 CONCLUSIONS AND RECOMMENDATIONS**

### **3.1 Conclusions**

- 46 I judge that the claims and arguments in those areas that I have sampled are acceptable for the purposes of Step 3 Generic Design Assessment, judged against the SAPs and other relevant standards and criteria.

- 47 I have identified no ROs, RIs or potential exclusions to date.

### **3.2 Recommendations**

- 48 From the perspective of Radiological Protection, it is recommended that the Westinghouse AP1000 design proceeds to Step 4 of the GDA process.

#### 4 REFERENCES

- 1 *AP1000 Pre-construction Safety Report*. UKP-GW-GL-732, Revision 1, Westinghouse Electric Company LLC, March 2009.
- 2 *ND BMS, Assessment Process*. AST/001, Issue 2, HSE, February 2003.
- 3 *ND BMS, Guide: Assessment Process*. G/AST/001, Issue 2, HSE, February 2003.
- 4 *Safety Assessment Principles for Nuclear Facilities*. 2006 Edition, Revision 1, HSE, January 2008.
- 5 *ND BMS, Technical Assessment Guide. Radiation Shielding*. T/AST/002, Issue 3, HSE, March 2009.
- 6 *ND BMS, Technical Assessment Guide. Fundamental Principles*. T/AST/ 004, Issue 2, HSE, November 2001
- 7 *ND BMS, Technical Assessment Guide. Radiological Protection*. T/AST/038, Issue 2, HSE, June 2009.
- 8 *ND BMS, Technical Assessment Guide. Radiological Analysis – Normal Operation*. T/AST/043, Issue 1, June 2009.
- 9 *ND BMS, Technical Assessment Guide. Radiological Analysis – Fault Conditions*, T/AST/045 Issue 1, HSE, June 2009.
- 10 *AP1000 European Design Control Document*. EPS-GW-GL-700, Revision 0, Westinghouse Electric Company LLC, 16 February 2009.
- 11 *Ionising Radiations Regulations 1999*, S.I. 1999 No. 3232.
- 12 *AP1000 Annual Occupational Dose Evaluation*, APP-SSAR-GSC-565, Revision 0, Westinghouse Electric Company LLC.
- 13 *Project Initiation Document, New Reactor Build, Generic Design Assessment Step 3, Radiation Protection*. ND Division 6 Project Initiation Document No. AR 09/006, HSE, June 2009. TRIM Ref. 2009/225562.
- 14 *Reactor Safety Reference Levels*. Issue O, Western European Nuclear Regulators' Association (WENRA), January 2008.
- 15 *IAEA Fundamental Safety Principles, Safety Fundamentals*. IAEA Safety Standards Series No. SF-1, International Atomic Energy Agency (IAEA) Vienna 2006.
- 16 *Safety of Nuclear Power Plants: Design – Requirements*. IAEA Safety Standards Series No. NS-R-1, International Atomic Energy Agency (IAEA) Vienna 2000.
- 17 *Work with Ionising Radiation, Ionising Radiations Regulations 1999, Approved Code of Practice and Guidance*, L121, HSE Books, 2000.
- 18 *Health and Safety at Work etc. Act 1974 c37, as amended*.
- 19 *Application of the 2007 Recommendations of the ICRP to the UK, Advice from the Health Protection Agency*. Documents of the Health Protection Agency, RCE-12, Radiation, Chemical and Environmental Hazards, 2009.
- 20 *New Nuclear Power Stations Generic Design Assessment – Guidance to Requesting Parties*. Version 3, HSE, August 2008.

**Table 1**

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

SAP Number	SAP Title	TAG	GDA Step	WENRA Reference*	IAEA Reference**
<b>Fundamental Principles</b>					
FP3	Optimisation of protection	T/AST/004	3 / 4	-	SP5 2.2, 2.4
FP4	Safety assessment	T/AST/004	3 / 4	-	-
FP5	Limitation of risk to individuals	T/AST/004 T/AST/038 T/AST/043 T/AST/045	3 / 4	E1.1	SP6 2.2
FP6	Prevention of accidents	T/AST/004 T/AST/045	3 / 4	E2.1	SP8 2.4 ,2.5, 2.8
FP7	Emergency preparedness and response	T/AST/004	3 / 4	R1.1	SP9 2.5, 2.8
FP8	Protection of present and future generations	T/AST/004 T/AST/038	3 / 4	-	SP7 2.2, 2.6 to 2.8
<b>Radiation Protection</b>					
RP1	Normal operation	T/AST/038	3 / 4	E1.1	2.4, 4.9 to 4.13, 6.99 to 6.106
RP2	Accident conditions	T/AST/038	3 / 4	E1.1	2.7, 2.8, 4.11 to 4.13
RP3	Designated areas	T/AST/038	3 / 4	E1.1	6.103
RP4	Contaminated areas	T/AST/038	3 / 4	E1.1	6.103
RP5	Decontamination	T/AST/038	3 / 4	E1.1	6.104
RP6	Shielding	T/AST/002 T/AST/038	3 / 4	E1.1	6.102
<b>Numerical Targets and Legal Limits</b>					
NT1	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/05 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.

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

**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
<b>Fundamental Principles</b>			
FP3	Optimisation of protection	Normal operation: Yes Accident conditions: No	Normal operation: Yes Accident conditions: No
FP4	Safety assessment	Yes	Yes
FP5	Limitation of risk to individuals	Yes	Yes
FP6	Prevention of accidents	No	No
FP7	Emergency preparedness and response	No	No
FP8	Protection of present and future generations	Yes	Yes
<b>Radiation Protection</b>			
RP1	Normal operation	Yes	Yes
RP2	Accident conditions	No	No
RP3	Designated areas	Yes	Yes
RP4	Contaminated areas	Yes	Yes
RP5	Decontamination	Yes	Yes
RP6	Shielding	No	No
<b>Numerical Targets and Legal Limits</b>			
NT1	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	Yes
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
Target 9	Total risk of 100 or more fatalities	No	No
NT.2	Time at risk	No	No



## Annex 1

### Assessment of AP1000 PCSR and Supporting Documentation against Standards and Criteria

#### A1 NUMERICAL TARGETS AND LEGAL LIMITS

- 1 SAP **NT.1** is *“A safety case should be assessed against numerical targets and legal limits for normal operation, design basis faults, and radiological accident risks to people on and off the site”*.
- 2 SAP **NT.2** is *“There should be sufficient control of radiological hazards at all times”*.
3. Para. 570 of SAPs explains that the targets are guides to inspectors to indicate where there is the need for consideration of additional safety measures. Nine sections of numerical targets / legal limits are given in SAPs, some of which are divided into sub-sections (e.g. on-site and off site).
4. For ease of presentation and understanding I have divided this annex into the various Radiological Protection topic areas (e.g. A2 routine occupational exposure). The relevant criteria and standards are addressed in each of these sections. For some topic areas there are no relevant numerical targets / legal limit sections, and for others there are one or more sections or sub-sections. In each topic area I have considered the relevant targets, or parts of targets.

#### A2 ROUTINE OCCUPATIONAL EXPOSURE

##### A2.1 Standards and Criteria For Routine Occupational Exposure

5. SAP **RP.1** (normal operation) states *“Adequate protection against exposure to radiation and radioactive substances in normal operation should be provided in those parts of the facility to which access needs to be gained”*. Para. 476 of SAPs explains that adequate protection is *“that level of protection that ensures compliance with the ALARP requirements of all relevant legislation, where appropriate to the SAPs, and takes into account the latest modern standards”*. In my section on standards and criteria (paras 14 to 19) I explain in detail the requirements for limitation and optimisation.
6. The numerical levels relevant to routine occupational exposure are:

**Target 1** – Any Person On The Site (effective dose in a calendar year):

Employees working with ionising radiation:

BSL(LL): 20 mSv

BSO: 1 mSv

Other employees on the site:

BSL: 2 mSv

BSO: 0.1 mSv

**Target 2** Any Group On The Site (average effective dose in a calendar year)

Defined groups of employees working with ionising radiation:

BSL: 10 mSv

BSO: 0.5 mSv

Further guidance is given in SAPs paras 476 to 484 and 583 to 589, and in TA / AST / 038 (Ref. 7). Success in meeting the criteria explained above will also contribute to meeting the relevant Fundamental Principle SAPs identified in the Project Initiation Document (PID) as being relevant to this Radiological Protection Assessment. For routine occupational exposure these are **FP.3**, **FP.4**, **FP.5** and **FP.8**.

7. There are other measures that will contribute to optimisation of occupational exposures but which are dealt with in particular detail in SAPs RP.3 to RP.6. I discuss these explicitly in the section entitled Further Radiological Protection Plant Design Features later in this Annex.

## **A2.2 Assessment of RP's Claims and Arguments against the Standards and Criteria For Routine Occupational Exposure**

- 8 My strategy for assessing the Requesting Party's (RP's) claims and arguments for routine occupational exposure was to review the Pre-construction Safety Report (PCSR), Design Control Document (DCD) (Ref. 10) and other supporting documentation against, primarily, achievement of ALARP exposures by means consistent with the hierarchy of control measures as explained in Section 2.2 of my report. This is the primary obligation in law and, if met, largely ensures that the SAPs enumerated above will be met.
- 9 Occupational exposure during normal operation is discussed in Chapter 13 of the PCSR and in more detail in Chapter 12 of the DCD. The RP asserts that the As Low As Reasonably Achievable (ALARA) policy is applied at all design stages, and for all design aspects, of the AP1000. In relation to minimisation occupational radiation exposure the RP cites in particular:
- core and fuel design, which minimise fundamental radiation sources;
  - operational chemistry, which supports excellent fuel performance;
  - purification systems;
  - choice of materials;
  - shielding;
  - automation; and
  - overall simplification of the plant.
- 10 The collective annualised occupational radiation exposure given in Section 12.4 of the DCD, was 0.67 person-Sv. However, this had recently been updated to more accurately consider improvements in materials and operational chemistry made in the design (Ref. 12). The total projected occupational radiation exposure was revised down to 0.22 person-Sv per year. This includes normal operations, refuelling operations, and routine maintenance.
- 11 A Technical Query (TQ) and subsequent discussions with the RP have highlighted the following:
- The annual dose estimate of 0.22 person-Sv takes into account dose reduction designs, technologies and methods that will be incorporated in the AP1000 and were not credited in the annual dose estimates shown in the DCD. Specifically, further dose reduction was achieved by addressing the occupational dose reductions from:
    - a) low-cobalt tubing within the steam generators;
    - b) no-cobalt valves on portions of the RCS; and
    - c) depleted zinc chemistry addition to the RCS.

- Additionally, dose estimate reductions on steam generator tasks were also obtained by electro-polishing the steam generator channel heads to reduce surface contamination. Numerical reduction factors for each of these measures were calculated based upon data taken from existing operating plants where the dose reduction strategy or a similar technology has already been implemented.
  - Apart from the impact of dose reduction technologies, the revised annual dose estimate of 0.22 person-Sv also reflects improvements over time in annual doses actually achieved for existing Westinghouse PWRs that are currently operating.
  - The initial AP1000 dose estimate was made in 2002 but developed from a 1992 assessment for the AP600. It is shown in the DCD as 0.671 person-Sv and was based upon a review of tasks and doses from operating Westinghouse two loop PWRs with corrections applied for the AP1000 design. At the time of this initial estimate, the annual doses for the best Westinghouse designed two loop plants averaged 1.62 person-Sv. When the AP1000 dose estimate was reviewed and updated, outage doses for the same plants averaged 0.90 person-Sv. The anticipated outage interval is now 18 months, and this improvement in personnel doses for existing plants is reflected in the revised dose estimate of 0.22 person-Sv.
  - The culmination of the application of additional dose reduction technologies and methods, along with improvements in existing Westinghouse-designed PWR doses resulted in an annual dose estimate of 0.22 person-Sv.
- 12 Comparison of this figure with the SAPs numerical targets and limits is not completely straight forward since firstly, the analysis given in the DCD was based on a collective dose three times higher, and secondly the implications for individual doses and doses to small groups of workers depend on the staffing levels employed by the eventual operator, and their deployment. However, taking a total workforce of around 400, of whom half work with radiation, (see PCSR page 449), i.e. a mean annual exposure below 1 mSv for radiation workers, it is clear is that exposures will be much lower than the BSLs, and close to the BSOs. Hence the primary focus is simply on achievement of ALARP. I note that the claimed collective dose achieved is exemplary; however, examination of detailed evidence will be the key area in Step 4 GDA. The RP has clearly met the internal target of 1 person-Sv, however this does not have a significant bearing on my assessment against the standards and criteria explained above.

### **A2.3 Conclusions**

- 13 I conclude that the RP's approach to occupational radiation exposure, and in particular with the requirements for ALARP, is consistent with the standards and criteria listed above, and commensurate with the UK approach and hierarchy of control measures. The arguments given in the submission and ancillary information to support the claims made are sufficiently robust for the purposes of Step 3 GDA assessed against relevant SAPs.

### **A3 FURTHER RADIOLOGICAL PROTECTION PLANT DESIGN FEATURES**

- 14 In the section above on routine occupational exposure I address the pre-eminent requirements for ALARP and how these have been addressed by the RP. This has covered many of the features of design, however, there are some further matters where specific more prescriptive standards and criteria apply, which I address below. Naturally these will also further contribute to optimisation of protection.

**A3.1 Standards and Criteria for Further Radiological Protection Plant Design Features**

15 There are 4 SAPs of particular relevance:

SAP **RP.3** (Designated Areas) is *“Where appropriate, designated areas should be further divided, with associated controls, to restrict exposure and prevent the spread of radioactive substances”*

SAP **RP.4** (Contaminated Areas) is *“Appropriate provisions for protecting persons entering and working in contaminated areas should be provided”*

SAP **RP.5** (Decontamination) is *“Suitable and sufficient decontamination provisions for the people, the facility, its plant and equipment should be provided”*

SAP **RP.6** (Shielding) is *“Where shielding has been identified as a means of restricting dose, it should be effective under all conditions”*

16 Guidance to Inspectors in carrying out assessment against the above principles is provided in the TAGs (see Table 1). My assessment below is restricted to those matters that go beyond my assessment against ALARP in other sections.

**A3.2 Assessment of RP’s Claims and Arguments against the Further Radiological Protection Plant Design Features****A3.2.1 Designated Areas, Contaminated Areas and Decontamination**

17 None of the numerical levels is directly applicable to this topic.

18 These three areas are intimately related. Radiological area designation and control is described in Chapter 12 of the DCD, particularly in Section 12.3 (which includes comprehensive detailed layouts). Further information was provided by the RP in response to TQs.

19 Access control, zoning, and personnel movements are considered in plant layout to reduce the potential for spread of contamination. The design layout gives plant areas categorised into radiation zones according to the design basis radiation levels and anticipated personnel occupancy. Access to the Radiologically Controlled Area (RCA) which includes the containment, and potentially contaminated areas of the annex, auxiliary, and radwaste buildings, is normally through the entry / exit area of the health physics section of the annex building.

20 Potential sources of internal radiation exposure are identified in Table 13.3-1 of the PCSR. The key isotopes involved are tritium, Carbon 14, activation products, particularly, Cobalt 58, Cobalt 60, Iron 55, Iron 59, Manganese 56, Manganese 54, Chromium-51, and fission products. Information on their origin and design features to minimise their impact are given.

21 Considerable attention has been paid to this area in design detail. For example, pipe systems are welded to minimise the potential for leakage, drip trays provided at points of potential leakage, floor drains for removal of radioactive leakage, covering of concrete surfaces with a smooth coating to facilitate decontamination, etc.

22 Handling of contaminated replacement parts is addressed. The most significant of these are primary filter cartridges, for which remote tools and shielded transfer casks will be provided. The cartridges are packaged and the packaging decontaminated in the truck bay of the auxiliary building, or in the radwaste building. Decontamination equipment and space for most equipment is provided as part of the hot machine shop, located in the annex building. Very large items may be decontaminated in the cask washdown pit in the auxiliary building. Considerable detail is provided in the DCD (Section 11.4). This area overlaps with the radwaste area and so has received attention from other assessors.

- 23 Reactor coolant pumps are designed to require infrequent maintenance and inspection; however, when maintenance or replacement is required the pump can be removed and moved to a low radiation area using a specially provided pump removal cart.
- 24 Para. 488 of SAPs states “There should be provision for monitoring and controlling the spread of airborne activity and contamination within and beyond each area”. I have not addressed the ventilation system and associated air contamination monitoring system. This area will be carried forward into step 4.
- 25 The DCD provides a large amount of information on shielding. I have addressed the impact of shielding in respect of ALARP in other sections of my report. However, I have not performed an assessment against SAP RP.6 of the claims and arguments in the particularly specialist area of shielding calculations and codes.

### A3.3 Conclusions

- 26 It is important to note that the SAPs are intended not just for assessment of design of new facilities but also for assessment of safety cases and reviews of existing facilities. This section is of limited applicability, especially for generic assessment, and it is noted in many places in the RPs submission that particular matters will be for the licensee. I have taken this into account in my assessment in that the design needs to provide appropriate facilities and layout, but equally many matters must await phase 2 of the process. I conclude that, for the purposes of step 3 GDA appropriate attention has been given to the designation of areas, contamination control and decontamination. I judge that the RP has provided adequate arguments against SAPs RP.3 to RP.5. I shall consider shielding and RP.6 at Step 4, including the possibility of employing a technical support contractor.

## A4 ROUTINE PUBLIC EXPOSURE

### A4.1 Standards and Criteria for Routine Public Exposure

- 27 Dose constraints (see Section 2.2 of my report):  
SAPs para. 590: dose constraint 0.3 mSv  
HPA advice: dose constraint 0.15 mSv
- 28 SAPs **Target 3** – Any Person Off The Site (effective dose in a calendar year):  
BSL(LL): 1 mSv  
BSO: 0.02 mSv
- 29 It is important to note that regulation of public radiation exposure is shared between the Environment Agency and HSE. The EA leads on doses to the public resulting from discharges of radioactive waste into the environment during normal operation, and EA assessors are considering this for GDA. HSE leads on doses to the public resulting from direct radiation originating from within the site boundary during normal operation. Therefore, I have restricted my assessment to consideration of direct radiation, whilst bearing in mind the potential additivity with discharges.

### A4.2 Assessment of RP’s Claims and Arguments Against the Standards and Criteria For Routine Public Exposure

- 30 In Section 13.2.7 of the PCSR the RP makes the following statement: “As a standard plant with a site as yet unspecified, offsite dose calculations are not possible at this point. This target, that covers both direct and inhaled / digested dose, should be addressed as part of the site selection phase”. If this was all that was said I would see this as problematical as I

would expect claims and arguments at Step 3 in relation to the standards and criteria listed in Section A4.1 above.

- 31 However, in contradiction to its statement that I quote above, the RP presents an argument in the PCSR (Section 13.2.7) that the direct radiation dose at the perimeter fence will be substantially less than 0.01 mSv per year, i.e. substantially less than half the BSO. The argument presented is based on experience at US plants and, significantly, at Sizewell B, together with the impact of design improvements on dose rate reductions.
- 32 Clearly habit survey information would be needed for a real site in order to calculate an actual reference group dose. However it is implausible that a realistic reference group would have unshielded 24 / 7 occupancy right up against the worst point on the site boundary. Thus reference group doses would be still lower, i.e. much less than the BSO. I therefore accept that, for Step 3 GDA (claims and arguments), public doses will meet the numerical standards and criteria.
- 33 The RP does not present a detailed ALARP assessment for public dose from direct radiation. SAPs state that below the BSO inspectors need not seek further improvements from the dutyholder but can confine themselves to assessing the validity of the arguments that the dutyholder has presented. Since I do accept the arguments I have not pursued this further at Step 3. However Step 4 requires claims, arguments and evidence and it will therefore be necessary to revisit this area at that time, and not leave it as a matter for Phase 2 (Site Licensing).

#### A4.3 Conclusions

- 34 For routine public exposure from direct radiation I judge that the RP's claims and arguments are adequate for step 3 measured against the relevant criteria and standards. In Step 4 I shall be expecting evidence to support those claims and arguments; the RP's assertion that this *"...should be addressed as part of the site selection phase"* is not appropriate.

#### A5 EXPOSURES OF PERSONS FROM FAULTS AND ACCIDENTS

- 35 The key standards and criteria for exposures of persons from faults and accidents are:

SAP **RP.2** (Accident Conditions) is "Adequate protection against exposure to radiation and radioactive contamination in accident conditions, should they occur, should be provided in those parts of the facility to which access needs to be gained. This should include prevention or mitigation of accident consequences."

The numerical levels in SAPs relevant to Exposures of Persons From Faults and Accidents are:

- 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

- 36 The RP's claims and arguments in respect of SAP RP.2 are given in the DCD in Chapter 12. Methods incorporated to minimise radiation exposure to workers include shielding, automation, and overall design approach of the plant. I have not undertaken any assessment of this at Step 3, and it will therefore be a candidate area for detailed assessment of claims, arguments and evidence at GDA Step 4.
- 37 The numerical levels (Targets 4 to 9) are largely the prerogative of, and have received extensive consideration by, other assessors during step 3. During GDA Step 4 I shall assess the RP's claims, arguments and evidence in respect of Level 3 Probabilistic Safety Analysis (PSA) in close liaison with other assessors dealing with Level 2 PSA.

**Annex 2 – Radiological Protection (including Level 3 PSA) – Status of Regulatory Issues and Observations**

<b>RI / RO Identifier</b>	<b>Date Raised</b>	<b>Title</b>	<b>Status</b>	<b>Required timescale (GDA Step 4 / Phase 2)</b>
<b>Regulatory Issues</b>				
None				
<b>Regulatory Observations</b>				
None				