New Reactors Programme

GDA close-out for the AP1000 reactor

GDA Issue GI-AP1000-FS-01: Spent Fuel Pool Safety Case

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EXECUTIVE SUMMARY

Westinghouse Electric Company LLC (Westinghouse) is the reactor design company for the **AP1000®** reactor. Westinghouse completed Generic Design Assessment (GDA) Step 4 in 2011 and paused the regulatory process. It achieved an Interim Design Acceptance Confirmation (IDAC) which had 51 GDA Issues attached to it. These issues require resolution prior to the award of a Design Acceptance Confirmation (DAC) and before any nuclear safety-related construction can begin on site. Westinghouse re-entered GDA in 2014 to close the 51 GDA Issues.

This report is the Office for Nuclear Regulation's (ONR's) assessment of the Westinghouse **AP1000** reactor design in the area of fault studies. Specifically, this report addresses GDA Issue GI-AP1000-FS-01: Spent Fuel Pool Safety Case.

During GDA Step 4, Westinghouse identified significant improvements to its original documentation to formalise some of the original **AP1000** design intent for spent fuel pool loss of cooling and loss of water inventory events within the (fault studies) safety case. The revised safety case claims and arguments were assessed and broadly welcomed by ONR's fault studies team; however, this GDA Issue was considered necessary because:

- The submissions were supplied late in the GDA process and it was not possible to consider how well they had been incorporated into the Pre-Construction Safety Report (PCSR) in particular chapters of the PCSR not directly associated with fault studies.
- Insufficient information was provided in the safety case to explain what would happen if a fault occurred in the spent fuel pool (for example, a loss of power or a leak) coincident with a routine operation involving the movement of a fuel assembly above the storage racks being undertaken.
- It was not clear if the Normal Residual Heat Removal System (RNS) would be available to cool the spent fuel pool without restriction, given that it has a safety role to provide to the reactor.
- The revised safety case was dependent on two (welcomed) modifications to the original **AP1000** design being implemented.

Central to Westinghouse's approach to close the GDA Issue has been to demonstrate the rigour of its own Design Change Proposal (DCP) process, which it has used to consolidate its responses to the various aspects of the GDA Issue. It has used a new DCP to identify changes to previously submitted documentation, supplement the technical requirements established by earlier design changes, identify new documents that will need to be created in the future, and to provide a link to supporting lower-tier references written in support of this GDA Issue.

My assessment conclusions are:

- The updated PCSR published at the end of this GDA Issue closure phase will adequately summarise the spent fuel pool safety case developed during GDA Step 4.
- The two modifications identified during GDA Step 4 are sufficiently well developed for GDA and unambiguously part of the UK **AP1000** design, and I have confidence that they will be fully implemented in the future using Westinghouse's normal internal processes for design changes.
- Westinghouse has addressed in its updated PCSR (and supporting documentation) the two areas of uncertainty identified in GDA Step 4 associated with fuel assemblies being moved above the racks and availability controls on the RNS.

My judgement is based upon multiple meetings with Westinghouse, a detailed review of its consolidating DCP and an inspection of its DCP process (including the computer database tool that is used).

The following matter remains, which is for a future licensee to consider and take forward in its site-specific safety submissions. This matter does not undermine the generic safety submission and requires licensee input / decision.

- CP-AF-AP1000-FS-01: The licensee shall demonstrate through a combination of analysis, human factors evaluations and trials that fuel handling procedures on how and when to manually place a fuel assembly into a safe location are both feasible and are consistent with applicable statutory and site dose limits.

In summary, I am satisfied that GDA Issue GI-AP1000-FS-01 can be closed.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
CCS	Component Cooling Water System
DAC	Design Acceptance Confirmation
DBA	Design Basis Analysis
DCP	Design Change Proposal
EDCD	European Design Control Document
FPS	Fire Protection System
GDA	Generic Design Assessment
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IDAC	Interim Design Acceptance Confirmation
IRR99	Ionising Radiations Regulations 1999
MDEP	Multinational Design Evaluation Programme
ONR	Office for Nuclear Regulation
P&ID	Piping and Instrumentation Diagrams
PCSR	Pre-construction Safety Report
PSA	Probabilistic Safety Analysis
REPPIR	Radiation (Emergency Preparedness and Public Information) Regulations 2001
RNS	Normal Residual Heat Removal System
RP	Radiation Protection
RWS	Raw Water System
SAPs	Safety Assessment Principles
SFS	Spent Fuel Pool Cooling System
SSC	Structure, System and Component
SWS	Service Water System
TSC	Technical Support Contractor
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1.1 Background

1. Westinghouse Electric Company LLC (Westinghouse) is the reactor design company for the **AP1000®** reactor. Westinghouse completed Generic Design Assessment (GDA) Step 4 in 2011 and paused the regulatory process. It achieved an Interim Design Acceptance Confirmation (IDAC) which had 51 GDA Issues attached to it. These issues require resolution prior to the award of a Design Acceptance Confirmation (DAC) and before any nuclear safety-related construction can begin on site. Westinghouse re-entered GDA in 2014 to close the 51 GDA Issues.

2. This report is the Office for Nuclear Regulation's (ONR's) assessment of the Westinghouse **AP1000** reactor design in the area of fault studies. Specifically, this report addresses GDA Issue GI-AP1000-FS-01 "Spent fuel pool safety case".

3. The related GDA Step 4 report (Ref. 1) is published on our website (www.onr.org.uk/new-reactors/ap1000/reports.htm), and this provides the assessment underpinning the GDA Issue. Further information on the GDA process in general is also available on our website (www.onr.org.uk/new-reactors/index.htm).

1.2 Overview of GI-AP1000-FS-01

4. During GDA Step 4, Westinghouse identified significant improvements to its original documentation to formalise some of the original **AP1000** design intent for spent fuel pool loss of cooling and loss of water inventory events within the (fault studies) safety case (Ref. 1). The revised safety case claims and arguments were assessed and broadly welcomed by ONR's fault studies team but they were submitted late in the GDA process and it was not possible to consider how well they had been incorporated into the Pre-Construction Safety Report (PCSR), in particular chapters of the PCSR not directly associated with fault studies.

5. Despite the welcomed improvements, at the end of GDA Step 4 ONR still had two outstanding issues on the safety case for the spent fuel pool:

- Insufficient explanation was provided in the safety case to explain what would happen if fuel was being moved above the storage racks at the time a fault occurred in the spent fuel pool (e.g. a loss of power or a leak).
- As a result of the UK-specific changes to the **AP1000** safety case, the Normal Residual Heat Removal System (RNS) is claimed to have a safety role for both the reactor and spent fuel pool. However, the availability controls (ie restrictions on the length of time a system can be out of service) only considered the RNS's reactor role.

6. Westinghouse itself identified two design modifications that would be needed to support the revised safety case:

- The addition of passive filters to the fuel handling area relief panel to mitigate the off-site radiological consequences from steam produced from the spent fuel pool if it was without active cooling for an extended period.
- The provision of an engineered connection from the firefighting water system to the component cooling water to provide an alternative heat sink to the active spent fuel pool cooling systems.

7. As a result of these points, at the end of GDA Step 4 it was considered necessary to raise GI-AP1000-FS-01 placing three Actions on Westinghouse:

- Action 1: The design basis case developed in GDA Step 4 for the spent fuel pool for the fault studies topic area needs to be cascaded into other technical areas and any new claims clearly identified in the PCSR.
- Action 2: Westinghouse to complete the design change process for the identified modifications to the spent fuel pool active cooling system and relief panels.
- Action 3: Westinghouse to update the relevant parts of the safety case to address outstanding concerns on the consequences of a fault occurring while fuel is being moved above the racks, and on competing claims in the availability of the RNS.

1.3 Scope

8. The scope of this assessment is detailed in the assessment plan (Ref. 2). Consistent with this plan, the assessment is restricted to considering whether the Westinghouse submissions to ONR for GI-AP1000-FS-01 (and its associated three Actions) provide a response sufficient to justify closure of the GDA Issue. As such, this report only presents the assessment undertaken as part of the resolution of this GDA Issue and it is recommended that this report be read in conjunction with the Step 4 fault studies assessment of the Westinghouse **AP1000** (Ref. 1) to appreciate the totality of the assessment of the evidence on the spent fuel pool safety case undertaken as part of the GDA process.

9. With respect to Action 1, no attempt has been made to assess the totality of the **AP1000** PCSR looking for all mention of the spent fuel pool. While a comprehensive PCSR was produced by Westinghouse in 2011 at the end of GDA Step 4 (Ref. 3), it was not assessed by ONR. There was no expectation that Ref. 3 could fully or even partially address all of the requirements of Action 1, given that it was largely written before the spent fuel pool safety case was clarified. Since the resumption of the GDA process and the commencement of interactions with Westinghouse on this GDA Issue, the PCSR has been undergoing iterative and staggered updates across its various chapters. Therefore, there was not a single consolidated PCSR available to review for spent fuel pool references. Instead, the pragmatic approach adopted by Westinghouse was to supply mark-ups to specified chapters and sections to be included in a future revision of the PCSR.

10. The design changes identified for Action 2 had already been considered and welcomed by ONR in GDA Step 4. Therefore, the assessment in this report is not looking at the appropriateness of these modifications. Instead, it is focused on whether Westinghouse has developed its original proposals to a level sufficient for GDA, and that the processes put in place will ensure that the currently understood functional requirements, standards and documentation update requirements are captured such that they can be considered when more detailed design work is completed in the future. To do this, not only has it been necessary to assess written submissions (ie a traditional assessment) but it has also been necessary to meet with Westinghouse to discuss its design change processes and examine its internal management systems. It is important to note that this examination of Westinghouse's design change processes has been very limited and does not constitute a repeat of the assessment undertaken during GDA Step 4 as part of the Management of Safety and Quality Assurance (Ref. 4).

11. The assessment required for Action 3 has been more conventional. The GDA Step 4 assessment identified two significant gaps in the spent fuel pool safety case. To judge whether the GDA Issue has been adequately addressed, safety case submissions supplied by Westinghouse have been assessed against the relevant Safety Assessment Principles (SAPs).

1.4 Method

12. This assessment has been undertaken consistent with internal guidance on the mechanics of assessment within ONR (Ref. 5).

2 ASSESSMENT STRATEGY

2.1 Pre-Construction Safety Report

13. ONR's GDA Guidance to Requesting Parties (Ref. 6) states that the information required for GDA may be in the form of a PCSR, and the Technical Assessment Guide NS-TAST-GD-051 sets out regulatory expectations for a PCSR (Ref. 7).

14. At the end of Step 4, ONR and the Environment Agency raised GDA Issue GI-AP1000-CC-02 (Ref. 8) requiring that Westinghouse submit a consolidated PCSR and associated references to provide the claims, arguments and evidence to substantiate the adequacy of the **AP1000** design reference point.

15. A separate regulatory assessment report has been written to consider the adequacy of the PCSR and closure of GDA Issue GI-AP1000-CC-02, and therefore (as has already been stated) this report does not attempt to assess the totality of the **AP1000** PCSR looking for mentions of the spent fuel pool and associated systems. However, looking at the adequacy with which the key safety case claims and arguments for spent fuel pool faults are included within the PCSR (and supporting references) is a fundamental aspect of this assessment, notably for Actions 1 and 3.

2.2 Standards and Criteria

16. The assessment has been undertaken in line with the requirements of the HOW2 BMS document NS-PER-GD-014 (Ref. 9). In addition, the SAPs (Ref. 10) constitute the regulatory principles against which duty holders' safety cases are judged, and, therefore, they are the basis for ONR's nuclear safety assessment. The SAPs 2014 Edition (Revision 0) has been used when performing the assessment described in this report (the original Step 4 fault studies assessment used the 2006 Edition).

2.2.1 Safety Assessment Principles and Technical Assessment Guides

17. The following SAPs (Ref. 10) were identified in the assessment plan (Ref. 2) as being appropriate to judge the adequacy of the arguments in the area of fault studies for the UK **AP1000**.

- Fault Analysis SAPs FA.1 to FA.9
- Severe Accidents SAPs FA.15 and FA.16
- Engineering SAPs EKP.2 to EKP.5, ECS.1, ECS.2, EDR.1 to EDR.4, ESS.2, ESS.4, ESS.6 to ESS.9, ESS.11, ERC.1 to ERC.3, EHT.1 to EHT.4
- Computer Codes and Calculation Methods SAPs AV.1 to AV.8
- Numerical Target for DBA Consequences Target 4.

18. It is important to note, however, that the scope of the assessment to close out the GDA Issue is narrowly defined and is less than that of a typical ONR assessment, such as that undertaken in GDA Step 4. The original fault studies assessment (Ref. 1), which resulted in GI-AP1000-FS-01, considered the SAPs identified above. The objective of this assessment is primarily to judge the adequacy with which Westinghouse's submissions address the requirements of the GDA Issue, rather than repeat the original assessment against the SAPs.

19. For Action 1, in assessing how the spent fuel pool safety case is captured in the PCSR, I have considered the requirements of SAPs SC.2 and SC.4, which state:

- The safety case process should produce safety cases that facilitate safe operation.
- A safety case should be accurate, objective and demonstrably complete for its intended purpose.

20. For Action 2, I have not attempted to compare how Westinghouse's internal processes compare with ONR's expectations (for example, as set out in NS-TAST-GD-057 Revision 3 on Design Safety Assurance, Ref. 11). This was already done in GDA Step 4 as part of Ref. 4. Instead, I have simply looked at how Westinghouse has taken the identified design changes through its own processes.

21. There are two aspects to Action 3. The need for a consideration of availability controls for the RNS resulted from a comprehensive review against the fault studies-related SAPs. I considered fewer SAPs when assessing the relevant aspect of the response to Action 3:

- SAP FA.6, notably the expectation that correct performance of safety-related and non-safety equipment should not be assumed where this would alleviate the consequences and failures consequential upon the initiating fault, and the need to consider failures expected to occur in combination with that initiating fault arising from a common cause.
- SAP FA.9, notably the expectation that Design Basis Analysis (DBA) should provide the basis for conditions governing permitted plant configurations, the availability of safety systems and safety-related equipment, and the safe operating envelope for the facility.

22. The second aspect of Action 3 is associated with arrangements to safely manage fuel stranded above the spent fuel racks during an event. This has the potential to reduce the amount of shielding between the operator and fuel being stored underwater. The Radiation Protection (RP) series of SAPs provide guidance to ONR assessors when considering the requirements of the Ionising Radiations Regulations 1999 (IRR99) and the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR). SAP RP.2 sets the expectation: "Adequate protection against exposure to radiation and radioactive contamination should be provided in those parts of the facility that will need to be accessed during faults or as part of accident management." SAP RP.6 states: "Where shielding has been identified as a means of restricting dose, it should be effective under all normal operation and fault conditions where it provides this safety function," with an associated clause "[the safety case should take into account]…the potential for unplanned or uncontrolled movement or loss of shielding (particularly when the shielding is provided by a liquid medium, e.g. in spent fuel ponds)".

2.2.2 National and international standards and guidance

23. There are both International Atomic Energy Agency (IAEA) standards (Ref. 12) and Western European Regulators' Nuclear Association (WENRA) Reference Levels (Ref. 13) that are relevant to the fault studies assessment of the **AP1000**. The original GDA fault studies assessment undertaken during Steps 3 and 4 took cognisance of the international standards published at the time. The GDA Issues that emerged from that original assessment can generally be characterised as having their origins in the application of the SAPs and UK-relevant good practice rather than through comparison with international guidance. Therefore, the SAPs (and not the international references) will be the foremost standards considered. It should be noted that the latest version of the SAPs (Ref. 10) were benchmarked against the extant IAEA and WENRA guidance in 2014.

2.3 Use of Technical Support Contractors

24. No Technical Support Contractors (TSCs) have been used in this assessment.

2.4 Integration with Other Assessment Topics

25. GDA requires the submission of an adequate, coherent and holistic generic safety case. Regulatory assessment cannot therefore be carried out in isolation as there are often safety issues of a multi-topic or cross-cutting nature.

26. To assess the adequacy of the submissions provided by Westinghouse for GI-AP1000-FS-01, I have required limited input from other technical disciplines. However, the submissions for the three Actions do have implications beyond the fault studies topic area.

27. As part of ONR's assessment of the cross-cutting GDA Issue GI-AP1000-CC-02 on the PCSR, colleagues from all disciplines will need to review separate chapters of the PCSR to come to a view on changes introduced by Westinghouse to Ref. 3. Westinghouse's response to Actions 1 and 3 has resulted in proposed changes to several sections of the PCSR (and supporting references), notably on Heating, Ventilation and Air Conditioning (HVAC) and availability controls. I have brought these proposed changes to the attention of mechanical engineering and electrical engineering colleagues so that they can consider them as part of their wider PCSR review.

28. As part of the work to close out GI-AP1000-FS-01 Action 2, I have looked at how Westinghouse takes forward modifications to the design, both those that apply to the "standard" **AP1000** plant (i.e. being progressed internationally) and those that just apply to the **AP1000** design proposed for the UK. The two modifications considered as part of Action 2 have effectively served as test cases (as part of ONR's sampling approach to assessment) to look at Westinghouse's approach to design changes. The intelligence gained from this assessment has been shared widely among the ONR **AP1000** assessment team through internal briefings and the circulation of contact records.

29. For Action 3, I have sought informal technical advice from colleagues who are specialists in RP and shielding legislation / analysis to assist me in reaching my conclusions on the adequacy of the safety case arguments submitted.

2.5 Out of Scope Items

30. This assessment report on GI-AP1000-FS-01 has focused on the adequacy of Westinghouse's spent fuel pool safety case for loss of active cooling and loss of water inventory events. A separate GDA Issue, GI-AP1000-RP-01 (Ref. 14), identified concerns with the original criticality safety case and Westinghouse's response to this GDA Issue has been assessed outside of this report (although the impact of the resolution of GI-AP1000-RP-01 on assumed spent fuel decay heat levels has been considered).

31. Action 3 of GI-AP1000-FS-01 includes a requirement for Westinghouse to consider the availability requirements of the RNS. During GDA Step 4, the broader GDA Issue GI-AP1000-CC-01 (Ref. 15) was raised for Westinghouse to detail arrangements to identify and advise a future licensee of the conditions and limits necessary in the interests of safety (including availability requirements). This assessment report does not attempt to comment on the adequacy of Westinghouse's response to GI-AP1000-CC-01. Instead, it makes the significant assumption that Westinghouse's generic arrangements for controlling the availability of key systems (as set out in Westinghouse's response to GI-AP1000-CC-01) are adequate and the approach for the RNS will be following these arrangements.

3 REQUESTING PARTY'S DELIVERABLES IN RESPONSE TO THE GDA ISSUE

3.1 Starting Position

32. The objective of this GDA Issue was not to get a design basis safety case for the spent fuel pool to allow a broad fault studies assessment. This was already secured in GDA Steps 3 and 4.

33. ONR's GDA Step 4 fault studies assessment (Ref. 1) explains in detail how Westinghouse revised its safety case for the spent fuel pool from that originally presented to ONR at the start of GDA Step 3. This was principally in response to Regulatory Observation RO-AP1000-054 (Ref. 32) raised on the adequacy of the shutdown and spent fuel pool fault safety case. Westinghouse's response to RO-AP1000-054 was Ref. 16.

34. Unchanged from Westinghouse's original spent fuel pool safety case were the following key claims that are fundamental to the design and philosophy of the **AP1000**:

- The **AP1000** design provides enough water inventory from Class 1 passive sources to ensure that the fuel [in the racks] will remain covered for at least 72 hours following all design basis events, even assuming unavailability of all non-Class 1 systems.
- If a complete loss of cooling is assumed, there is a potential for the spent fuel pool water to boil. However, even during refuelling scenarios, it would take at least three hours for the pool to begin boiling. The integrity of the spent fuel in the racks is maintained as long as it remains covered (boiling of the water is an efficient means of removing the spent fuel's decay heat).
- There are a number of piping connections to the spent fuel pool which, in the event of a break, could result in both a reduction in water inventory and a loss of cooling. A break in the Class 2 (non-seismically qualified) pipework of the Spent Fuel Pool Cooling System (SFS) with an associated reduction in water level is assumed in the 72-hour water inventory calculations that support the claim above.

35. Among the key changes to the safety case were:

- Revised safety claims on the Class 2 active cooling chain and Class 3 / non-classified operational systems such that they minimise the demands on the Class 1 passive systems. The design is such that the probability of onset of boiling is estimated to be $< 5 \times 10^{-4}$ per year.
- In support of the probability figure attributed to the onset of boiling, a design change to include an engineered connection from the Fire Protection System (FPS) to the Component Cooling Water System (CCS) to provide an alternative heat sink to the active spent fuel pool cooling systems needs to be credited.
- The standard **AP1000** design has a relief panel which opens to atmosphere to release the steam generated in a loss of active cooling event. To meet UK-relevant good practice, Westinghouse proposed the addition of passive filters to the fuel handling area relief panel to mitigate the off-site radiological consequences.
- Despite all piping connected to the pool being seismic Category 1 (apart from the SFS pipework) and it not being under the load path of any lifting machinery, a break in a Class 1 pipe connected to the SFP was analysed as an infrequent design basis fault to show that the **AP1000** design provides a significant window of time before the fuel is uncovered and hence, considering the low probability of occurrence of these events, consequential fuel uncovery is not considered credible.

36. The starting point of this assessment report is that these changes are now established as part of the **AP1000** safety case and they are not subject to reassessment. However, the PCSR does need to be updated to reflect these safety case claims and arguments (Action 1), the identified design changes need to be implemented (Action 2), and the two gaps identified in the spent fuel pool safety case need to be addressed (Action 3).

3.2 Submissions to Address the GDA Issue

37. To address the three Actions of this GDA Issue, Westinghouse originally envisaged a need for only a limited amount of new documentation. It proposed to supply to ONR:

- an update to the topic report produced during GDA Step 4 capturing the spent fuel pool safety case (Ref. 16);
- an update to the March 2011 PCSR (Ref. 3);
- an already approved and incorporated standard plant DCP (APP-GW-GEE-2070) to modify the RNS design (Ref. 17); and
- an already approved UK-specific DCP (APP-GW-GEE-2517) to add passive filters to the fuel handling area relief panel (Ref. 18).

38. Early interactions with Westinghouse established that additional and more extensive submissions would be required to close out the three Actions of the GDA Issue. The strategy Westinghouse arrived at was to generate a new DCP (APP-GW-GEE-5151 Revision 0, Ref. 19) to consolidate the response to the various aspects of the GDA Issue (which has an impact on several documents) in a single place. This DCP includes the following:

- A response to the requirements of GI-AP1000-FS-01 Action 3 to ensure the **AP1000** safety case adequately considers the consequences of a fault occurring while fuel is being moved above the racks.
- Further information to that originally provided in APP-GW-GEE-2517 Revision 0 (Ref. 18) on the component and design requirements for adding passive filters to the fuel handling area relief panel (in response to GI-AP1000-FS-01 Action 2).
- A response to the requirements of GI-AP1000-FS-01 Action 3 to consider the availability requirements placed on the RNS by the spent fuel pool, in addition to those already identified by reactor events.
- Mark-ups to the European Design Control Document (EDCD) (Ref. 20) to reflect changes resulting from Westinghouse's work to address GI-AP1000-FS-01.
- Mark-ups to the topic report produced during GDA Step 4 capturing the spent fuel pool safety case (Ref. 16).
- Mark-ups to the PCSR (Ref. 3) to address the requirements of GI-AP1000-FS-01 Action 1 (ie to make sure the claims, arguments and evidence resulting from Ref. 16 are cascaded throughout the PCSR) and to incorporate any new developments from addressing Actions 2 and 3 of the GDA Issue.

39. In addition to Ref. 19, Westinghouse also submitted:

- under cover of a letter (Ref. 21), extracts from the March 2011 PCSR (Ref. 3) highlighting where the implications of design changes Ref 17 and 19 were already incorporated into the document (Ref. 22);
- an update to the GDA Step 4 spent fuel pool safety case (Ref. 23), incorporating the changes identified in Ref. 19;
- a report in support of Ref. 19 and the requirements of GI-AP1000-FS-01 Action 3 on the human response and the environment in the fuel handling area during a loss of power event with stranded fuel (Ref. 24);

- three marked-up Piping and Instrumentation Diagrams (P&IDs) showing the changes to the FPS, CCS and RNS introduced as a result of the work to address GI-AP1000-FS-01 Action 2 (Ref. 25);
- a Westinghouse internal technical memo (Ref. 26) to complement DCPs Ref 17 and 19 providing extracts from relevant P&IDs and identifying additional changes to UK-specific documents that were missed when the standard plant DCP APP-GW-GEE-2070 (Ref. 17) was incorporated (in support of GI-AP1000-FS-01 Action 2);
- in response to an ONR regulatory query, additional background information to support Ref. 19 and GI-AP1000-FS-01 Action 3 on stranded fuel (Ref. 27).
- under cover of a letter (Ref. 28), additional and corrected availability controls to those included in Ref. 19 (Ref. 29), revised mark-ups to PCSR showing the implementation of the changes flagged in Ref. 19 (Ref. 30) and an extract from the fault schedule showing how the spent fuel pool safety case is summarised (Ref. 31).

40. ONR’s assessment of the adequacy of Westinghouse’s response to GI-AP1000-FS-01 has mainly been undertaken using these documents, supported by regular discussions with Westinghouse.

4 ONR ASSESSMENT OF GDA ISSUE GI-AP1000-FS-01

41. My assessment of Westinghouse's submissions for GI-AP1000-FS-01 is set out below, against the scope defined in Section 1 and strategy discussed in Section 2.

42. The requirements of the three Actions are quite different and, as a result, I have assessed each of them separately in the following subsections. For each, I have started by providing more background information to that already provided to give context to my assessment.

43. A conclusion is provided for each Action, and in the case of Action 3, an Assessment Finding has been raised for a future licensee to address.

4.1 Assessment of GI-AP1000-FS-01 Action 1

4.1.1 Background

44. Westinghouse's revised safety case for the spent fuel pool (Ref. 16) was reviewed in GDA Step 4 by ONR's fault studies assessors and judged to be broadly adequate (the significant gaps being captured in GI-AP1000-FS-01 Action 3). However, because the safety case provided as part of the response to a fault studies regulatory observation was received late on in the GDA Step 4 process, it was not possible for ONR to comment on how it had been (or needed to be) incorporated into the PCSR.

45. The need to consider the adequacy with which the revised safety case was included in the PCSR extended beyond the fault studies discipline. For example, the changes to the HVAC design would be relevant to the mechanical engineering discipline, clarifications on the load paths over Class 1 pipework are relevant to internal hazards, and revised claims on active cooling systems (which need power) are relevant to electrical engineering. For these reasons, Action 1 of GI-AP1000-FS-01 was raised.

4.1.2 Assessment

46. The fundamental objective of this part of my assessment of GI-AP1000-FS-01 is to check that the relevant aspects of the PCSR and supporting references are accurate, objective and demonstrably complete (SAP SC.4). The underlying technical arguments and evidence had already been assessed against relevant fault analysis SAPs during GDA Step 4. The distribution of information between the top-level PCSR and the supporting references is, to a great extent, a matter of choice and preference for Westinghouse. However, for my assessment, I was looking for visibility of the major claims and design features, especially those that have changed from the original safety case documentation, such that future safety case authors and operators will not miss them (SAP SC.2).

47. Westinghouse produced its March 2011 PCSR (Ref. 3) with an intention that it would include the revised spent fuel pool safety case as established by Ref. 16, including the two DCPs to the spent fuel pool active cooling system and the relief panel. This was not formally assessed by ONR during GDA Step 4 so a key starting point for this assessment has been to look at the existing reference. To aid this review, during the early interactions on the work required to close out this GDA Issue Action, Westinghouse supplied Ref. 33 highlighting some aspects of the **AP1000** safety case that already capture the revised claims and arguments (in particular, from the two design changes).

48. Through the interactions with ONR, Westinghouse identified the need for additional updates and additions to the PCSR (ie not already included in Ref. 3). Some of these updates were associated with its work to address Action 3 of GI-AP1000-FS-01 but others came from a fresh look at the completeness with which the UK spent fuel pool

safety case is captured within the PCSR. To allow this GDA Issue Action to be closed out before the submission of Revision 1 of the PCSR (due at the end of the GDA Issue Closure Phase), Westinghouse used Attachment D of Ref. 19 to capture proposed mark-ups to the PCSR. In addition, Westinghouse has used extracts from the PCSR to preview what the impacted sections will eventually look like (Ref. 30). I have therefore used these (Refs 19 and 30), along with the extant version of the PCSR (Ref. 3) to come to my judgements on the adequacy with which Action 1 has been addressed.

49. The safety case for spent fuel pool faults (including criticality faults as well as loss of cooling and water inventory faults) is captured within Section 9.11 of Ref. 3 (ie as part of the Internally Initiated Faults Chapter describing the fault studies safety case for the reactor and other facilities). Large portions of Ref. 16 (already assessed by ONR during GDA Step 4) have been included wholesale within the PCSR with just minor changes to references and the non-inclusion of some of the detailed tables of information that are included in supporting reference. The level of detail included within the PCSR goes beyond what I might have expected; it would have been acceptable for the PCSR to summarise succinctly some aspects of the supporting Ref. 16. However, it does make it easier for me to confirm that the PCSR does incorporate the revised spent fuel pool safety case and that it has been updated (compared to safety documentation for the standard plant).

50. Ref. 19 includes extracts from the PCSR and highlights sections that demonstrate that Westinghouse has included the two notable DCPs (Refs 17 and 18) at a high level. This is sufficient for Action 1, although as I will discuss in Section 4.2 below, I required a greater level of detail (in submissions and references other than the PCSR) to conclude that the design changes have been implemented sufficiently for GDA in order to close out Action 2.

51. Significantly for my assessment, Westinghouse has appropriately not just limited the updates to the PCSR to Chapter 9. Ref. 19 shows that:

- Updates have been made to the Chapter 6 (Plant Description and Operation) section associated with fuel handling area ventilation, and the Appendix 6A (Review of Major **AP1000** Design Decisions) section on alternative sources of cooling for the RNS heat exchangers.
- Updates have been made to Chapter 14 (Result and Conclusions – Fault Analysis) to add a section on alternative sources of cooling to the RNS heat exchangers.[1]
- A section has been included in Appendix 23A (**AP1000** Nuclear Ventilation – Comparison with UK Practice and Best Available Technology Assessment) commenting on the inclusion of the filters for fault conditions and linking these to environmental best available technique discussions.

52. The main safety case submission assessed during GDA Step 4 was not the PCSR (it had not been completed in time). Instead, it was the EDCD (Ref. 20) that was considered. Westinghouse no longer plans to maintain this document. As it is a major reference to Ref. 3, information from it either needs to be incorporated into the next revision of the PCSR or included in standalone documents that can be referenced from the PCSR. At the time of this assessment, the migration from Ref. 20 was not complete and Westinghouse's internal design modification processes required relevant changes to it to be identified (even though it is highly unlikely that these changes will ever be implemented in a new revision of the EDCD). As a result, Ref. 19 identifies changes to the EDCD despite the existence of the PCSR.

[1] In Revision 1 of the PCSR produced at the end of this GDA Issue closure phase of work (Ref. 43), the changes for Chapter 14 were incorporated into Appendix 6A and not the preliminary location identified by Ref. 19.

53. Some of the EDCD changes are reflected in the PCSR but others are to sections that are not included in the PCSR. It is acceptable for Westinghouse to choose to put some information into lower-level safety case documentation (and in some very rare cases, exclude aspects of the EDCD altogether from the safety case because they are not relevant to the UK safety case). However, notable exclusions from the PCSR are detailed availability controls on key systems (referred to by Westinghouse as "technical specifications" and "short-term availability controls") which are included within Chapter 16 of Ref. 20 but are not within the PCSR.

54. In Section 4.3 I comment on the acceptability of the (technical) changes proposed by Westinghouse to the availability requirements resulting from the spent fuel pool safety case. The general adequacy of Westinghouse's proposals for capturing limits and conditions (including availability control) from the totality of the AP1000 GDA safety case outside the PCSR is subject to a separate GDA Issue (Ref. 15). However, assuming for the purposes of this assessment that Westinghouse's general approach is adequate, I am satisfied that spent fuel pool availability controls have been appropriately identified from the fault studies aspects of the safety case (consistent with SAP FA.9) and the sentencing of Ref. 19 through Westinghouse's DCP process should ensure that they will appear in relevant documentation in due course.

4.1.3 Conclusions

55. The adequacy of Westinghouse's spent fuel pool safety case (the fault studies aspects) was assessed during GDA Step 4 (Ref. 1). The main requirement of GI-AP1000-FS-01 Action 1 was to include the revised spent fuel pool safety case in the PCSR, including in chapters not directly associated with the fault studies topic area. As a result of my review of Westinghouse's submissions, I am satisfied that Westinghouse has addressed this requirement. I have reached this conclusion principally by assessing the interim submissions of Refs 19 and 30, which provided mark-ups to the PCSR, on the assumption that the final PCSR will eventually reflect these documents.

56. Taking the PCSR and Ref. 19 collectively to be the top-tier reports of the spent fuel pool safety case, I am satisfied that the requirements of SAP SC.4 (for them to be accurate, objective and demonstrably complete for their intended purposes) have been met. It is important to recognise that the intended purpose is not to support operations, rather it is to support the assessment of generic design before construction has started. As the **AP1000** plant proceeds through site licensing, commissioning and then operation, the spent fuel pool safety case will need to develop, expand and potentially change.

57. Consideration of the expectation set out in SAP FA.9 for the DBA to provide the main basis for setting permitted plant configurations and the availability of safety systems was an important aspect of my assessment, given that the UK **AP1000** safety case for the spent fuel pool puts claims on active cooling systems which are not credited in the EDCD (Ref. 20). I will discuss this further in Section 4.3 below as part of my assessment for Action 3, but I am content that these aspects are adequately captured in the broader safety case, even though they are not included in the PCSR.

4.2 Assessment of GI-AP1000-FS-01 Action 2

4.2.1 Background

58. A notable manifestation of the **AP1000** plant's passive features is its safety case for loss of active cooling from the spent fuel pool. Following a postulated complete loss of the Class 2 cooling chain, the pool will heat up and boil off water. However, as long as the fuel in the racks remains covered with water (even if it is boiling), Westinghouse's claim is that the fuel will be adequately cooled to prevent safety criteria being exceeded. The water inventory is thus the principal means (Class 1) of fulfilling the

Category A safety function of cooling the fuel in the spent fuel pool. The **AP1000** design provides enough water inventory from Class 1 sources to supplement the SFP water inventory to ensure that the fuel will remain covered, even assuming unavailability of all non-Class 1 systems, for at least 72 hours following all design basis events.

59. This safety case approach was reviewed, commented on and broadly accepted in the ONR GDA Steps 3 and 4 fault studies assessments (Ref. 1). However, two significant observations were made:

- While the fuel in the spent fuel would be adequately cooled in such a scenario, a significant amount of (slightly) radioactive steam would be generated from the pool. The **AP1000** spent fuel pool designers had allowed for this by installing a passive relief panel in the auxiliary building fuel handling area which will open and discharge steam to the atmosphere (in the event that active HVAC systems are not available). However, ONR judged that this open route to the environment did not meet its expectations on ventilation and the preservation of physical barriers to prevent the escape or relocation of radioactive material as set out in SAPs ECV.1, ECV.2 and FA.7 (Ref. 10).
- The active cooling systems should be sufficiently robust and well designed such that a complete loss of all active cooling (resulting in the spent fuel pool water heating up and eventually boiling) is an infrequent event (i.e. occurring with a frequency of $<1 \times 10^{-3}$ per year).

60. Westinghouse accepted these observations and identified two design changes that would be needed to support a revised safety case for the UK:

- The addition of passive filters to the fuel handling area relief panel to mitigate the off-site radiological consequences from the steam produced spent fuel pool without active cooling for an extended period.
- The provision of an engineered connection from the FPS to the CCS to provide an alternative heat sink to the active spent fuel pool cooling systems. This would provide additional defence-in-depth for spent fuel pool cooling in some fault scenarios, using the FPS water on a once-through basis to remove heat from the CCS (which in turn removes heat from the RNS and SFS).

61. During GDA Step 4, Westinghouse indicated to ONR that DCPs for these two modifications had been written (APP-GW-GEE-2517 and APP-GW-GEE-2070 respectively). ONR welcomed this but at the time the GDA Step 4 assessment was being finalised, the details of these design changes had not been seen and therefore the Action 2 was raised.

62. Both of these DCPs appeared in Table 5 of Revision 5 of the **AP1000** Design Reference Point for UK GDA (Ref. 34), which accompanied the IDAC. The intent of Table 5 was (and remains in the latest revisions) to summarise those changes identified in GDA Step 4 as part of the UK **AP1000** design. However, at the end of GDA Step 4 (ie in Revision 5 of Ref. 34) both DCPs were marked as being “unincorporated” into the safety case.

63. The objective of the assessment for Action 2 is therefore to come to a judgement on the adequacy / completeness with which the two DCPs address ONR’s Step 4 observations, and to what extent they have been appropriately implemented (to a level sufficient for GDA) into the latest design and safety case documentation.

4.2.2 Assessment

64. As an initial response to GI-AP1000-FS-01 Action 2, in early 2015 Westinghouse supplied to ONR the formal documentation for APP-GW-GEE-2517 Revision 0 (Ref. 18) and ONR APP-GW-GEE-2070 Revision 0 (Ref. 17). Westinghouse also provided Revision 6 of **AP1000** Design Reference Point for UK GDA (Ref. 34), which indicated that both changes had been “incorporated” into the safety case during the period the regulatory process in the UK had been paused. At face value, this addressed the requirements of the Action. However, I chose to examine in more detail the contents of the DCPs and what Westinghouse means when it states a design change is “incorporated”.

4.2.2.1 APP-GW-GEE-2517

65. DCP APP-GW-GEE-2517 (Ref. 18) is a UK-specific design change (ie the passive filters on the relief panel are not being installed on the “standard” plants being built in China and the US). It is a relatively short document, stating very briefly that the UK regulator (ie ONR) was asking for the principle of showing risks are reduced As Low As Reasonably Practicable (ALARP) to be applied to the steam release path and therefore Westinghouse is proposing the addition of passive filters. It then identifies a small number of high-level text changes to be added to the EDCD and some drawings (one of which is hand drawn) indicating where the filters should be located. Four standard plant lower-tier documents associated with ventilation are identified as needing to be replaced with UK-specific documents but no details about the requirements of these documents are provided.

66. Westinghouse stated early on during the interactions associated with this GDA Issue that it did not plan to create any UK-specific design documents until site licensing (ie beyond GDA). Instead, the DCPs (in this case APP-GW-GEE-2517) capture the requirements of a modification until such a time when the design work commences. Therefore, despite APP-GW-GEE-2517 being declared “incorporated” in Revision 6 of the design reference point, I was not satisfied that it demonstrated that the requirements of Action 2 had been met. The EDCD has not been updated since GDA Step 4 and Westinghouse has stated that it has no plans to do so. In principle, as part of Westinghouse’s wider work to migrate from the EDCD to a PCSR, some of these changes could be swept up, but I could not see any evidence that this would be systematically undertaken and controlled by the design control process applied to APP-GW-GEE-2517. More significantly, the details on the lower-level documents affected (or in need of being created) were very limited. In summary, despite the alteration in the DCP status (from unincorporated to incorporated) during the GDA pause, in my opinion the position had not moved significantly from GDA Step 4 when Action 2 was written.

4.2.2.2 APP-GW-GEE-2070

67. DCP APP-GW-GEE-2070 (Ref. 17) is different from APP-GW-GEE-2517 in that it has been applied to the standard plant. In an even earlier design change, Westinghouse had identified a requirement to add a connection from the FPS to the CCS that would allow FPS water to cool the RNS heat exchangers should a single fire or security event take out both Service Water System (SWS) and CCS trains. This was implemented to satisfy a US regulatory requirement to provide a diverse means to take the reactor to a cold shutdown state (Mode 5).

68. It was subsequently recognised that the flow rates provided by this original design change would be inadequate due to alternate flow paths that would be difficult to isolate. As result, Westinghouse wrote APP-GW-GEE-2070 to further enhance the FPS connection to the CCS by adding two butterfly isolation valves, which allow CCS flow rates up to 2,000 gallons per minute (gpm) from a single FPS pump. This is stated

to be sufficient to take the reactor to conditions defined in the technical specifications for Mode 5. It also identifies a discharge route for disposing of heated FPS water after it has passed through the RNS heat exchanger.

69. The changes identified in APP-GW-GEE-2070 (and declared as being incorporated in Revision 6 of Ref. 34) seem sensible and are welcomed. However, the DCP is clear that they are being made to address US regulatory requirements for fire protection, established to ensure that nuclear reactors have an alternative capability (in the case of the **AP1000** reactor, an alternative to the passive systems) of bringing the plant to a safe shutdown state. It was not written with a view to addressing ONR's observations on the spent fuel pool (the fact that an FPS connection to the CCS could service the SFS heat exchangers as well as the RNS heat exchangers is not mentioned). In addition, I could find no recognition in APP-GW-GEE-2070 that three other design changes included within Ref. 34 make significant modifications to the UK RNS, SFS, CCS and SWS design and layout (see Refs 35, 36 and 37). Therefore, on its own, I was not satisfied that a statement that APP-GW-GEE-2070 has been incorporated into the standard **AP1000** design was adequate to address Action 2.

70. I do acknowledge that the original topic report produced during GDA Step 4 capturing the spent fuel pool safety case (Ref. 16) did discuss why this change identified for another purpose would add to the robustness of the active spent fuel pool cooling. Ref. 16 states that with at least 325,000 gallons (US) of FPS water available and a further 625 gallons per minute of Raw Water System (RWS) makeup water available, the FPS connection would be able to sustain cooling for a heat load of approximately 8.8 MW in the spent fuel pool. However, none of this is discussed in the DCP and my concern was that this requirement could be "lost" over time and not included in all affected safety case and design documents if it is not captured in Westinghouse's formal design change process.

4.2.3 Westinghouse's design change process

71. To better understand Westinghouse's process for drafting, controlling, incorporating and tracking DCPs, I undertook an "inspection" at Westinghouse's UK offices using the changes identified for GI-AP1000-FS-01 as examples of the application of the process.

72. Details of this inspection are captured in Ref. 38. Not all of the details from the inspection are detailed in this assessment report but the following key observations are summarised:

- The **AP1000** design at a point in time is described by System Specification Documents (which are summarised in Table 2 of Ref. 34) and Design Specification Documents (which are summarised in Table 3 of Ref. 34).
- Lower-level documents such as datasheets and drawings are referenced from System Specification Documents and Design Specification Documents but they are not included in the design reference point.
- DCPs do not define the design or provide functional requirements. They do not represent "signed-off" design requirements.
- The UK **AP1000** design reference point, against which the PCSR is written (and supporting "licensing documents" and environmental / security reports), does include DCPs. So the PCSR could state that a particular UK-specific feature exists (or will exist) and take credit for it, even if a DCP is unincorporated. The PCSR is not a design document and therefore does not appear in the design reference point (Tables 1 to 3).
- Westinghouse reiterated that a DCP that was raised in, for example, Step 4, or during the "GDA pause" when Westinghouse was away from the UK, that applies to the standard plant (for example, APP-GW-GEE-2070) is likely to result in System Specification Documents and Design Specification Documents

being updated, as well as being reflected in any applicable licensing documents (US, China and, going forward, the UK PCSR).

- A DCP that is UK specific (for example, APP-GW-GEE-2517), whether raised during Step 4 or now, will not result in any changes being made to System Specification Documents and Design Specification Documents during GDA. This will not be done until site licensing and the start of detailed UK design work. However, “licensing documents” (the PCSR, basis of safety case reports etc) will be updated to reflect the DCP during GDA.
- Westinghouse uses a database tool to control the incorporation of DCPs. For any particular DCP, it will list all the documents impacted by the described change and whether they have been updated or not at the time the database is consulted.
- A DCP would be shown as incorporated in the design reference point report (Ref. 34) if all impacted documents identified in Tables 1 to 3 and the Master Submission List have been updated. However, there could be lower-level documents that the database is tracking that remain to be updated ie the database would say that a DCP remains unincorporated while the design reference point states it is incorporated.
- A modification identified in a partially incorporated DCP can be part of the design if, for example, a System Specification Document has been updated, while other documents (of potentially very low significance) remain to be updated. In other words, the modification does not become “live” in a “big bang” at the point at which the DCP is declared incorporated. Design documents are likely to be updated at different times. However, as stated above, UK-specific DCPs are highly unlikely to be reflected in the design documentation during GDA.

73. Crucially, this inspection provided me with a lot of confidence in Westinghouse’s processes for tracking DCPs through to completion / implementation in both the scenario where the change is being made to the standard plant (to be incorporated into the design in the near future, as per APP-GW-GEE-2070) and where the change is UK specific and will not be fully incorporated into the design until site licensing (ie as per APP-GW-GEE-2517). This confidence has been vital for me to come to judgement on whether this Action can be closed. However, I still considered the two DCPs that were being taken through the process to be inadequate on their own to close out Action 2, for the reasons stated above.

4.2.4 APP-GW-GEE-5151

74. As discussed in Section 3, to address ONR’s feedback on its initial submission to GI-AP1000-FS-01, Westinghouse chose to generate a new DCP (APP-GW-GEE-5151 Revision 0, Ref. 19) to consolidate the various aspects of its additional submissions in a single vehicle. A notable inclusion within APP-GW-GEE-5151 is more information on the requirements of the proposed passive filters and the impacted documents. Among the information provided are:

- excerpts from the original design change APP-GW-GEE-2517;
- a table of system component design requirements to be captured in future design documentation;
- table components that need to be modified to meet the requirements identified;
- drawings of the proposed design change;
- “datasheet” changes that will be made to supporting references to design documents (ie lower-tier documents than those that appear in Ref. 34);
- a long list of impacted licensing and design documents (much more extensive than the list given in APP-GW-GEE-2517); and
- mark-ups to the text to be included in the EDCD (identified in APP-GW-GEE-2517 but unlikely ever to be implemented) and mark-ups to the text to be included in the next revision of the PCSR.

75. This additional information, along with my better understanding of Westinghouse's design change process and how it is being applied to UK-specific modifications, was sufficient for me to conclude that the requirements of Action 2 have been met for the addition of passive filters. I am left in no doubt that requirement for such filters is part of the UK safety case for the **AP1000** spent fuel pool, this requirement will have sufficient and appropriate prominence in the PCSR, the DCP APP-GW-GEE-5151 systematically flags changes to design documents that will need to be made in the future, and Westinghouse's processes (using the SmartPlant database) should ensure the requirements are tracked and implemented at the appropriate times.

4.2.5 Other submissions

76. DCP APP-GW-GEE-5151 (Ref. 19) does not provide any significant additional discussion on the changes to the FPS to allow it to contribute to the claimed reliability of the spent fuel pool active cooling. However, Westinghouse wrote an internal technical memo (Ref. 26) which complements and corrects the original (reactor-focused) DCP APP-GW-GEE-2070 (Ref. 17) with UK-specific spent fuel pool discussion and mark-ups to UK-specific plant drawings (ie considers the modifications to the cooling water system design and layout established by Refs 35, 36 and 37). It also demonstrates some consideration of why implicitly US-centric discussions on fire hose connections and fittings are applicable to the UK.

77. Ref. 26 states that it is associated to design change APP-GW-GEE-2070 on Westinghouse's SmartPlant database such that it will be applied to the UK design documents at the appropriate time during site licensing.

78. I was already satisfied that the top-level safety case documentation (i.e. Refs 3 and 16) clearly state the requirement for the complete loss of active spent fuel pool cooling to be an infrequent fault, and this has been demonstrated by a Probabilistic Safety Analysis (PSA) evaluation crediting the ability to use the FPS to cool the RNS / SFS heat exchangers via the CCS connections. I am also satisfied that this capability has been provided on the standard plant by APP-GW-GEE-2070 (albeit to protect the reactor rather than the spent fuel pool). Crucially for closing this Action, Ref. 26 demonstrates consideration of the modified UK design for cooling water systems, including those systems provided to the spent fuel pool. Finally, as a result of the inspection of Westinghouse's processes discussed in Section 4.2.3, I am satisfied that UK-specific aspects included in Ref. 26 will be monitored, tracked and implemented at the appropriate time during site licensing.

4.2.6 Conclusion

79. As a result of the documentation supplied to ONR and the confidence Westinghouse has provided to me on its arrangements for managing design changes, I am satisfied that Action 2 of GI-AP1000-FS-01 has been addressed.

4.3 Assessment of GI-AP1000-FS-01 Action 3

4.3.1 Background

80. The ability to manage design basis faults for 72 hours using just passive safety features is a longstanding and fundamental design feature of the **AP1000** plant. As a result, Westinghouse has set out to reduce / eliminate claims on active systems which would feature prominently in the safety cases for other reactor designs. As has already been discussed, this approach has been applied to the spent fuel pool as well the reactor core.

81. Two obvious ways that active spent fuel pool cooling could be lost are through a loss of off-site power and a seismic event. In both cases, Westinghouse's original safety

case makes no claims on ac power supplies and instead credits the Class 1 passive measures as being sufficient to cool fuel assemblies in the spent fuel pool for at least 72 hours. However, during the GDA Step 3 and Step 4 fault studies assessment, it was clarified that the claims on fuel being adequately cooled applied to assemblies in the spent fuel pool racks. It will be necessary during normal operations to routinely handle and move fuel assemblies above the racks (notably, but not limited to, refuelling outages) using the ac power supplied fuel handling machine. Given Westinghouse's approach of limiting claims on active systems, it was asked in GDA Step 4 to explain either how its 72-hour calculations consider the possibility of fuel being stranded above the racks during a fault condition or how the fuel could be effectively and safely lowered back into the racks when the main sources of ac power are unavailable.

82. Westinghouse responded to this challenge by stating in Ref. 16 that fuel handling equipment drive mechanisms would be equipped with hand wheels that could be placed on the motor drive shafts to manually position the fuel-handling-machine bridge, trolley or hoist to allow the operators to bring a fuel assembly to a safe location. However, no further details were provided on the feasibility or practicalities of this claim, especially in deteriorating environmental conditions (ever-increasing heat, steam, and radiological dose) following a loss of cooling or loss of water inventory event. This resulted in one aspect of Action 3 being raised.

83. The second aspect of Action 3 relates to availability controls on active systems. Chapter 16 of the EDCD (Ref. 20) includes a set of technical specifications for the Class 1 passive safety systems and a set of controls described as "investment protection short-term availability controls" for some of the Class 2 active systems. It was agreed with Westinghouse that the detailed assessment of technical specifications (and by extension the short-term availability controls) would not be undertaken until site licensing. However, their basis and origins were considered at a high level during GDA Step 4.

84. It was established that both sets of controls are driven by US regulatory requirements. In the US, technical specifications are subject to significant regulatory oversight but only apply in certain criteria. Westinghouse states that the Class 2 active systems on the **AP1000** plant do not meet these criteria but it has still used PSA to gain insights into their role in protecting the utilities investment and for preventing / mitigating severe accidents. Ref. 20 states that these insights have been used to generate short-term availability controls that provide "reasonable assurance" that the Class 2 systems will be operable during anticipated events.

85. The role of the RNS (and the supporting CCS, SWS and standby diesels) in providing defence-in-depth to the reactor safety case has always been recognised by Westinghouse. As a result, there are short-term availability controls identified in Ref. 20 on these systems. However, the PSA approach adopted by Westinghouse was limited to considering the reactor. The concern set out in Action 3 was prompted by an apparent lack of recognition in the extant availability controls of the requirements on the RNS to support spent fuel pool cooling, either to supplement the SFS (in some shutdown modes) or instead of the SFS (in the case of breakdowns or planned maintenance). It was not clear if the RNS could be assumed to be fully available to deliver reactor safety functions (in the event of a problem with the reactor) if a train on the RNS is already in use to support the spent fuel pool. In addition, given that the revised UK safety case for the spent fuel pool (Refs 16 and 23) claims that the Class 2 active systems will reliably operate such that a complete loss of active cooling is an infrequent fault, a discussion on controls on when maintenance can be performed on the RNS, SFS, CCS, SWS and standby diesels was judged necessary, considering more than just reactor requirements.

4.3.2 Assessment

4.3.2.1 Fuel stranded above the spent fuel racks

86. Westinghouse's principal response to the challenge set out in Action 3 on stranded fuel is included within APP-GW-GEE-5151 (Ref. 19). Ref. 19 identifies:

- a need for the fuel handling machine and refuelling machine design specifications to state that manual operations shall be possible by two operators following a complete loss of power;
- test requirements to validate the functionality and force requirements to manually move the fuel handling machine;
- a need for additional battery-backed lighting both above the spent fuel pool and under the water;
- a need for fuel handling procedures to include criteria for when to manually place an assembly in the nearest safe location; and
- documents to be updated to capture these requirements.

87. Ref. 19 also states that there is sufficient time to manually place the fuel into a safe location before environmental and radiological conditions deteriorate to unsafe levels. A preliminary evaluation of the action sequence required to place a stranded fuel assembly into a safe location is provided; however, a more detailed analysis is postponed until site licensing through an entry on the "Human Factors Action Database" (see ONR's evaluation of GI-AP1000-HF-01, Ref. 39).

88. I welcome the intent and content of the APP-GW-GEE-5151. It increases the prominence of the claim on the ability to hand wind fuel to a safe location and ensures that this requirement is cascaded into the appropriate safety case and design documentation for the fuel handling equipment. However, even with the commitment to undertake more detailed human factors analysis in the future, I requested Westinghouse to provide further substantiation of its claims on the feasibility and safety of manually putting fuel assemblies in a safe place. I also considered it necessary for Westinghouse to demonstrate whether its proposals were ALARP, both in terms of protecting the fuel from damage (which could result in increased off-site radiological consequences) and protecting the operators lowering the fuel from the radiological and conventional hazards of the task.

89. As a result, Westinghouse wrote Ref. 24 to support its assertions on the feasibility of the proposed actions. Ref. 24 is identified in APP-GW-GEE-5151 and is referenced from Ref. 23.

90. I am satisfied that Ref. 24 sets out what actions would be required to place a stranded fuel assembly in a safe place and conservatively estimates how long this operation would take (less than 55 minutes, including a 30-minute delay for the operator to respond to prompts that there is a need to take action). I am also satisfied that it provides sufficient information (to a level appropriate for GDA) to support Westinghouse's claims that the fuel handling area will remain habitable in terms of temperature for long enough to perform the required operations (recognising that this will be confirmed during site licensing as part of the human factors commitment).[2]

91. As part of my assessment of adequacy of Westinghouse's arguments for the dose to operators from performing the required actions, I took cognisance of the requirements of SAPs RP.2 and RP.6 (see Section 2.2.1). Westinghouse initially proposed to show compliance with Target 4 in SAPs (200 mSv for an on-site dose for faults with an

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[2] *WEC has calculated in Ref. 24 that the fuel handling area wet bulb globe temperature will be below 35ºC or less for at least two hours, which will allow a stay time of one hour for a worker performing moderate work while wearing coveralls.*

initiating event frequency < 1 x 10^{-4} py). However, I considered the 20 mSv legal limit established in IRR99 and set out in Target 1 of the SAPs to be more appropriate (Ref. 10). This was because the changes proposed to the fuel handling procedures identified by APP-GW-GEE-5151 (Ref. 19) anticipate the operators staying at their posts in the fuel handling area to take the necessary actions, as opposed to evacuating (which is a feasible alternative course of action that could have been proposed). Both IRR99 and REPPIR require arrangements to be in place to deal with emergency situations.[3] Paragraph 590 of the SAPs states that "in planning for a radiation emergency, and noting the provision in REPPIR that IRR99 dose limits are dis-applied during such an emergency, the operator shall identify emergency exposure dose levels……and make appropriate arrangements for their application during such an emergency". However, Westinghouse's timing assumptions to complete all the necessary actions do not allow for the operators evacuating, appropriately authorised people setting higher dose limits, and then allowing the operators to re-enter the fuel handling area with health physics supervision.

92. As a result, a major aspect of my assessment for Action 3 was to be satisfied that the operators following procedures to lower stranded fuel into a safe position will not receive more than 20 mSv. To pursue this, in addition to reviewing the main submission identified above (Ref. 24), I also sought information on the acceptability of Westinghouse's position through a Regulatory Query (Ref. 40) and face-to-face discussions (Ref. 41).

93. Westinghouse states in Ref. 24 that if there is no loss of water inventory from the initial event (eg a loss of off-site power), then there will be no loss of shielding due to the evaporation of water for several hours. As a result, the radiation levels experience during the manual fuel lowering task will be effectively the same as during normal refuelling operations (circa 0.025 mSv/hr, well below the 20 mSv limit, assuming the actions take 55 minutes).

94. For loss of cooling events associated with a pipe break (including a seismic event), Westinghouse has assumed the water level instantaneously drops to the level of the non-seismically qualified SFS suction pipe.[4] This is still well above the spent fuel racks but is only 1.0 m above the fuel assembly being handled. This is illustrated in Figure 1.

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[3] REPPIR defines a Radiation Emergency as an event that is likely to result in any member of the public being exposed to ionising radiation in excess of 5 mSv over a period of a year. It is unlikely that this specific event (insufficient shielding of a stranded fuel assembly) will result in significant off-site dose (unless it is totally uncovered and overheats); however, the requirements emergency arrangements in place will exist from other events on the site and for IRR99.

[4] WEC has discounted the failure of the lower RNS pipework (seismic Class 1) in its stranded fuel considerations. The failure of RNS pipework has been considered as an infrequent fault in Ref. 16 and Ref. 30. However, if its failure is not associated with a seismic event, there is no reason for off-site power to be lost and therefore lowering fuel quickly into a safe location by normal means should not be a challenge. For the purposes of Action 3, I judge an assumption that the water level will only drop to the level of the higher SFS pipework to be reasonable.

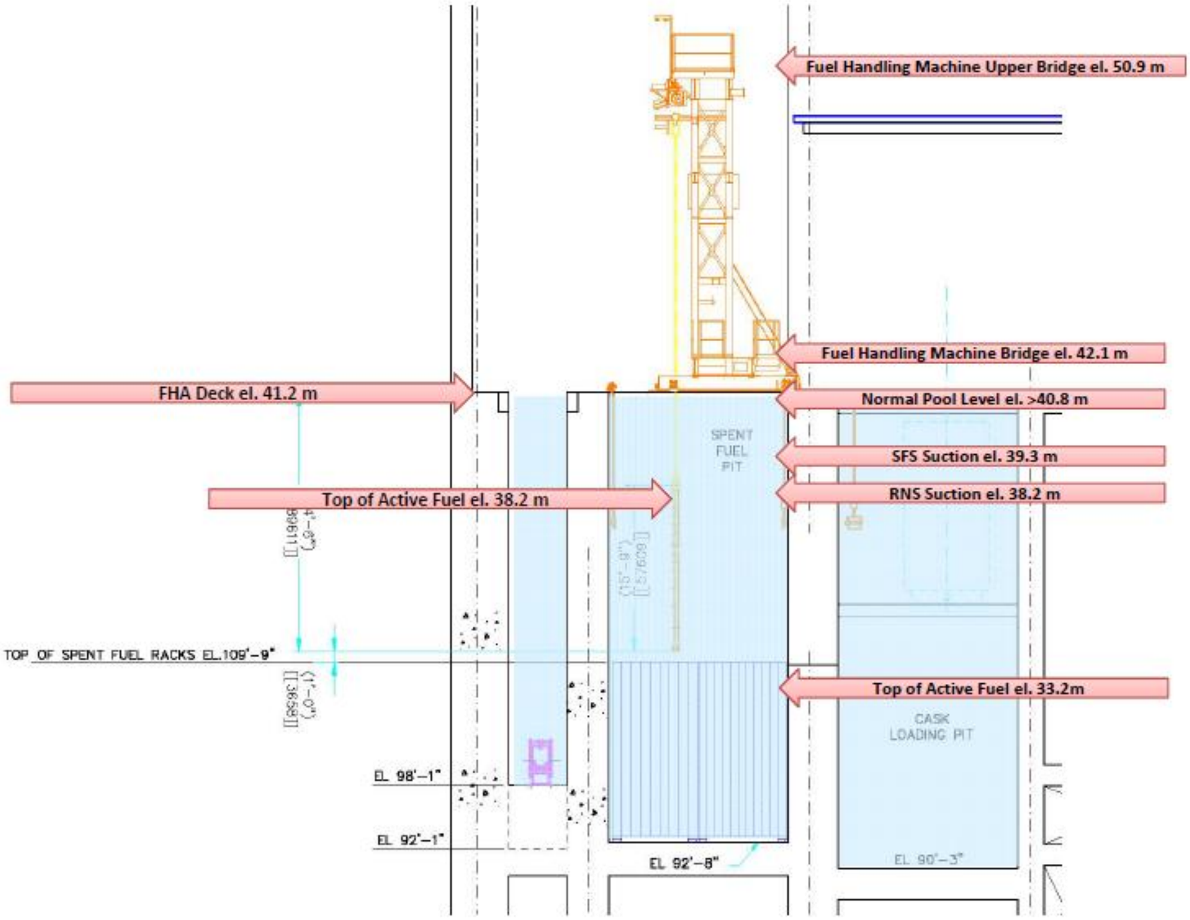

Figure 1: Illustration of key elevations during fuel handling operations in the spent fuel pool

95. Westinghouse has used the Microshield® computer code to undertake point-kernel gamma shielding calculations (Ref. 24). It has estimated that the dose rate to a worker should be less than 20 mSv, assuming the lowering operations take circa one hour and the worker is at the maximum dose location throughout that period. With more realistic assumptions about where the operators will be positioned to perform the different actions required to lower a fuel assembly into a safe location, Westinghouse has estimated a dose of less than 7 mSv could be anticipated. At face value, these evaluations do appear to support Westinghouse's claims and meet the requirements of SAP Target 1. However, Westinghouse did concede in discussions with ONR that its point-kernel gamma radiation calculations are not as accurate as methods using Monte Carlo techniques. Westinghouse also noted that it had not considered the contribution of neutron exposure which could be significant with only 1 m of water coverage.

96. Recognising this, Westinghouse has stated it will undertake further calculations during site licensing to confirm its initial estimates. If necessary, it will provide additional shielding to the fuel handling machine deck (the location of the highest dose) to achieve the appropriate dose levels.

97. If Westinghouse had stopped at this point, I would have considered the position unsatisfactory. However, Ref. 24 goes on to capture the output of an optioneering study on a wide range of potential improvements to the spent fuel pool and fuel handling systems as part of an ALARP demonstration. It has considered options to both reduce the time it would take to put an elevated fuel assembly into a safe place and to reduce the operator doses. I am broadly satisfied with this consideration of the

options. Some aspects of the ALARP discussion are a little unorthodox and perhaps misleading in that existing features of the design are presented as new options; however, I am content that these features do contribute to the "ALARP story" and I do not discount their relevance. The features that Westinghouse credits (some new, some longstanding) as being sufficient to demonstrate that the design is ALARP are:

- visual level indicators to provide the operators with quick notification of changing pool levels;
- additional emergency lighting for conducting operations after a loss of power (added through APP-GW-GEE-5151);
- the ability to connect the fuel handling machine to the standby diesel generators as an operator selectable load (it does not happen automatically) reducing the time to lower the fuel by approximately 15 minutes;
- the provision of portable rotating equipment (eg a drill) to improve the speed of manual movement of the fuel handling machine;
- level instrumentation linked to the main control room, used as a prompt to initiate makeup water to the spent fuel pool; and
- defence-in-depth means of providing makeup water, actuated either locally or from the main control room.

98. Ultimately, I am satisfied that Westinghouse is making a supportable claim that the operators will be able to manually place a stranded fuel assembly in a safe location if needed, and that there are features in place to help prompt the operators to take the necessary actions, to speed up those actions and to reduce the dose from that assumed in the conservative evaluation. The dose calculations are not definitive, a fact conceded by Westinghouse, but I am content that the methodology and assumptions presented in Ref. 24 are adequate for GDA. I do consider it necessary for compliance with appropriate dose limits to be demonstrated during site licensing (with modifications to the plant or procedures made if necessary), and as a result Assessment Finding CP-AF-AP1000-FS-01 has been raised. It is important to recognise that 20 mSv is the legal limit for effective dose in a calendar year for any person on the site but a licensee may impose a tighter administrative limit on dose uptake. The local procedures eventually implemented on what to do in the event of a spent fuel pool fault occurring while fuel is being handled will need to take cognisance of the licensee's policy on dose uptake in normal and fault conditions, and show that the procedures can still be completed as claimed in the GDA safety case.

CP-AF-AP1000-FS-01: The licensee shall demonstrate through a combination of analysis, human factors evaluations and trials that fuel handling procedures on how and when to manually place a fuel assembly into a safe location are both feasible and are consistent with applicable statutory and site dose limits.

4.3.2.2 Availability controls on systems providing active cooling to the spent fuel pool

99. SAP FA.9 (Ref. 10) sets an expectation that DBA should provide an input into establishing the limits and conditions for safe operation and identifying the requirement for operator actions. This includes the conditions governing permitted plant configurations and the availability of safety systems.

100. At the end of GDA Step 4, GDA Issue GI-AP1000-CC-01 (Ref. 15) was raised for Westinghouse to put forward a UK-specific methodology to identify limits and conditions on operation necessary in the interest of safety, including availability controls. As stated in Section 2.5, I am not assessing submissions and pre-empting the conclusions that will be reported elsewhere. I have limited my assessment to looking at the technical basis for the availability controls identified from the revised spent fuel pool safety case and its interaction with the reactor safety case, while making the assumption (confirmed by Westinghouse as being appropriate) that its US approach to

short-term availability controls will form the basis of its approach for active systems on the UK **AP1000** plant.

101. Westinghouse accepted the requirement to review its extant short-term availability controls and proposed some changes via APP-GW-GEE-5151 (Ref. 19) and Ref. 29, notably:

- A requirement to have both trains of RNS operable for reactor injection or spent fuel pool cooling during Modes 1, 2, 3 or 4 when the spent fuel pool decay heat is > 4MW.
- A requirement to have both trains of RNS operable for reactor injection or spent fuel pool cooling in Modes 5 and 6 when the primary reactor circuit is open.
- Planned maintenance on the RNS should be performed during Modes 1, 2 or 3 but only when the spent fuel pool decay heat is < 4MW. This is because the RNS is more important to achieving the declared risk figures during shutdown modes than it is during the modes identified above where it is a backup to the Class 1 passive systems.
- A requirement to have one train of SFS operable in all operating modes when the spent fuel pool decay heat is > 4MW.
- Planned maintenance on the redundant train of SFS should be performed when the spent fuel pool decay heat is < 4 MW.
- Two (out of three) ac power supplies[5] should be available in all operating modes when the spent fuel pool decay heat is > 4MW.

102. These availability controls are new and come from considering the requirements of Action 3 and the changes to the UK **AP1000** safety case. Ref. 29 states that the significance of 4 MW is that it is decay heat level, below which it takes the water in the spent fuel pool longer than eight hours to reach saturation following a loss of active cooling (at which point the provision of makeup water needs to be considered).[6] After several refuelling cycles when “normal” amounts of irradiated fuel are being routinely stored in the spent fuel pool, Westinghouse predicts that a 4 MW limit will only impose restrictions on the timing of maintenance during the first month of operations following a return to power.

103. Ref. 29 sets out some key considerations which resulted in these availability controls:

- Only one train of RNS is necessary to cool the reactor (once the RNS cut-in pressure / temperature is reached).
- Only one train of RNS or one train of SFS is necessary to prevent boiling in the spent fuel pool (although more may be needed to keep water temperatures in the normal operating window).
- The UK **AP1000** design for the RNS is capable of providing cooling to both the spent fuel pool and reactor at the same time due to the train separation.
- The UK **AP1000** design for the SFS is capable of providing cooling to both the spent fuel pool and refuelling cavity at the same time due to the train separation.

104. I agree with Westinghouse that these points are significant. They bring much greater visibility to the claims on the active Class 2 systems, which did not feature prominently in the original safety case submissions assessed in GDA Step 4 (which were dominated by claims on passive Class 1 systems). I am satisfied that the changes Westinghouse has identified address both the original intent of Action 3 and SAP FA.9.

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[5] *The three ac power supplies identified for the AP1000 are off-site power (ie the grid) and the two standby diesel generators.*
[6] *It is worth noting that 4 MW is identified by WEC (Ref. 23) as being the decay heat level at which no makeup water is needed to achieve spent fuel pool cooling for at least 72 hours (ie even if the pool is allowed to reach saturation, the fuel in the racks will not uncover for 72 hours).*

The deterministic considerations listed above supplement Westinghouse's original probabilistic approach for short-term availability controls and ensure that the additional / competing requirements of the spent fuel pool safety case have been considered. I am also satisfied with how the changes to short-term availability controls have been captured and will be implemented through the design change process discussed previously (assuming the assessment GI-AP1000-CC-01 is content with Westinghouse's broader strategy to document limits and conditions coming from the GDA safety case).

105. It should be noted that the revised availability controls do have some implications for the electrical engineering safety case, setting requirements for both sizing and maintenance. This has been separately reviewed as part of ONR's assessment of GDA Issue GI-AP1000-EE-01 (Ref. 42).

106. The resolution of GDA Issue GI-AP1000-RP-01 (Ref. 14) is expected to result in a reduction in the capacity of the UK **AP1000** spent fuel pool as part of a revised criticality case. This has been ignored by Westinghouse in its evaluations discussed in this report. I am satisfied by Westinghouse's rationale for decoupling its work for the two GDA Issues, notably the fact that the decay heat loading in the spent fuel pool is primarily from recently off-loaded fuel (tens of MW). A reduction in the capacity for storing "long cooled fuel" is likely to only change overall decay heat loading by less than 1 MW. Potentially an outcome of GI-AP1000-RP-01 could be a reduction in the time it takes to reach 4 MW and maintenance restrictions being lifted. While this could provide additional flexibility to a future operator, in practice the benefits are likely to be very small.

4.4 Assessment Findings

107. During my assessment, a single item on demonstrating the adequacy of fuel handling procedures was identified for a future licensee to take forward in its site-specific safety submissions (see Subsection 4.3.2). The details are repeated in Annex 1.

108. This matter does not undermine the generic safety submission and is primarily concerned with the provision of site-specific safety case evidence, which will usually become available as the project progresses through the detailed design, construction and commissioning stages. The item is captured as an Assessment Finding.

109. Residual matters are recorded as Assessment Findings if one or more of the following apply:

- site-specific information is required to resolve this matter;
- the way to resolve this matter depends on licensee design choices;
- the matter raised is related to operator-specific features / aspects / choices;
- the resolution of this matter requires licensee choices on organisational matters;
- to resolve this matter the plant needs to be at some stage of construction / commissioning.

110. The nature of the identified Assessment Finding is that almost all of these criteria apply.

5 CONCLUSIONS

111. This report presents the findings of the assessment of GDA Issue GI-AP1000-FS-01 relating to the **AP1000** GDA closure phase.

112. As a result of my assessment of Westinghouse's submissions for this GDA Issue, many meetings and discussions with Westinghouse, an inspection of Westinghouse's design change process and consultations with ONR's colleagues in different technical areas, my conclusions are:

- The updated PCSR published at the end of this GDA Issue closure phase will adequately summarise the spent fuel pool safety case developed during GDA Step 4.
- The two modifications identified during Step 4 are sufficiently well developed for GDA, are unambiguously part of the UK **AP1000** design and I have confidence that they will be appropriately fully implemented in the future using Westinghouse's normal internal processes for design changes.
- Westinghouse has addressed in its updated PCSR (and supporting documentation) the two areas of uncertainty identified in GDA Step 4 associated with fuel assemblies being moved above the racks and availability controls on the RNS.

113. A single Assessment Finding remains which is for a future licensee to consider and take forward in its site-specific safety submissions. This matter does not undermine the generic safety submission and requires licensee input / decisions.

- CP-AF-AP1000-FS-01: The licensee shall demonstrate through a combination of analysis, human factors evaluations and trials that fuel handling procedures on how and when to manually place a fuel assembly into a safe location are both feasible and are consistent with applicable statutory and site dose limits.

114. Ultimately, I am satisfied that GDA Issue GI-AP1000-FS-01 can be closed.

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Annex 1

Assessment Findings to be addressed during the Forward Programme

Assessment Finding Number	Assessment Finding	Report Section Reference
CP-AF-AP1000-FS-01	The licensee shall demonstrate through a combination of analysis, human factors evaluations and trials that fuel handling procedures on how and when to manually place a fuel assembly into a safe location are both feasible and are consistent with applicable statutory and site dose limits.	4.3.2