New Reactors Programme

GDA close-out for the AP1000 reactor

GDA Issue: Consider and action plans to address the lessons learnt from the Fukushima event GI-AP1000-CC-03

Assessment Report: ONR-NR-AR-16-039-AP1000
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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. At that point it received an Interim Design Acceptance Confirmation (IDAC) which had 51 GDA issues attached to it. These issues require resolution prior to the granting of a Design Acceptance Confirmation (DAC). This in turn is needed before any nuclear safety-related construction can begin on site. In August 2014 Westinghouse recommenced GDA of the **AP1000** reactor and began a programme to resolve the 51 issues.

This report presents the Office for Nuclear Regulation's (ONR's) and the Environment Agency's (EA's) assessment to confirm close-out of the GDA issue GI-AP1000-CC-03 Consider and action plans to address the lessons learnt from the Fukushima event and associated actions generated as a result of the GDA Step 4 cross-cutting topic – lessons learnt from the Fukushima event for the **AP1000** design. The assessment has focused on the deliverables identified within the resolution plan.

GDA Issue GI-AP1000-CC-03 was raised following the earthquake and tsunami which severely damaged the Fukushima Dai-ichi and Dai-ni nuclear power plants in Japan in March 2011. This event occurred during the later stages of **AP1000** GDA Step 4, meaning that a full understanding of the event and the lessons which needed to be learnt by the nuclear industry were not available at the issue of the IDAC. A full DAC could only be issued when the **AP1000** design could be assessed within the context of the Fukushima lessons learnt.

The GDA issue consists of two actions:

- GI-AP1000-CC-03.A1: Westinghouse to address the lessons learnt from its internal review following the Fukushima event relevant to GDA for the **AP1000** plant.
- GI-AP1000-CC-03.A2: Westinghouse to address the lessons learnt that are relevant to GDA for the **AP1000** plant from HM Chief Inspector's interim and final reports.

Westinghouse has provided two reports as deliverables to resolve GI-AP1000-CC-03:

- A UK **AP1000** Plant Post-Fukushima Assessment: this report documents Westinghouse's comprehensive, standalone post-Fukushima response for the UK context. This is Westinghouse's major submission.
- An assessment of International Fukushima Lessons Learned Reports: this report documents the individual approaches, goals and safety enhancements that the various countries are taking to address Fukushima lessons learnt. This is a supplementary submission to the UK **AP1000** Plant Post-Fukushima Assessment addressing international post-Fukushima lessons learnt.

As a consequence of the receipt of these deliverables and my assessment of them, I conclude that:

- Westinghouse's response to GDA Issue GI-AP1000-CC-03 provides a thorough and comprehensive review of post-Fukushima lessons learnt and demonstrates the **AP1000** plant's robustness against a wide range of external hazard challenges.
- Westinghouse has adequately addressed the recommendations set out in the HM Chief Inspector's interim and final reports and the UK national stress test findings (STFs).
- Westinghouse has considered a wide range of international lessons learnt from the Fukushima event as part of its review.
- Potential safety enhancements to the **AP1000** design were suitably identified, considered and screened against as low as reasonably practicable (ALARP) considerations as appropriate for GDA.

- The **AP1000** design safety has been enhanced as a result of the lessons learnt from the Fukushima event.

My judgement is based upon the following factors:

- Westinghouse delivering clear reports in line with its resolution plan.
- Interactions between Westinghouse and ONR throughout the resolution of the issue have ensured that the final report is in accordance with regulatory expectations.
- Westinghouse has identified reasonably practicable safety enhancements and has incorporated them into the **AP1000** design.

In addition, I have reviewed the updated Pre-Construction Safety Report (PCSR) in the areas where this issue has impact and I am satisfied that the outcome of the GDA issue resolution has been adequately reflected within it.

The following matter remains, which is for the future licensee to 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-CC03-01: The licensee shall consider the practicability of installing a level indication for the spent fuel pool (SFP) capable of providing water level indication below top of fuel height. Such indication is desirable in order to provide situational awareness of SFP coolant inventory during beyond design basis (BDB) events.

In summary, I am satisfied that GDA Issue GI-AP1000-CC-03 can be closed.

LIST OF ABBREVIATIONS

AC	Alternating Current
ADG	Ancillary Diesel Generator
AF	Assessment Finding
ALARP	As Low As Reasonably Practicable
AP1000 ®	Westinghouse Electric Company PWR design
ASME	American Society of Mechanical Engineers
BDB	Beyond Design Basis
BSL	Basic Safety Level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
BWR	Boiling Water Reactor
C&I	Control and Instrumentation
CCS	Component Cooling Water System
DAC	Design Acceptance Confirmation
DAS	Diverse Actuation System
DC	Direct Current
DCP	Design Change Proposal
DG	Diesel Generator
DRP	Design Reference Point
DWS	Demineralised Water Transfer and Storage System
EA	Environment Agency
EDCD	European Design Control Document
ENSREG	European Nuclear Safety Regulators Group
EPR	European Pressurised-water Reactor
FR	Final Recommendation
FPS	Fire Protection System
GDA	Generic Design Assessment
HCLPF	High Confidence of Low Probability of Failure
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IDAC	Interim Design Acceptance Confirmation
IDS	Class 1 DC and Uninterruptible Power Supply System
INPO	Institute of Nuclear Plant Operations
IR	Interim Recommendation
LOCA	Loss of Coolant Accident
LOOP	Loss of Off-site Power
LUHS	Loss of Ultimate Heat Sink
MCCI	Molten Core Concrete Interaction
MCR	Main Control Room
MDEP	Multinational Design Evaluation Programme
NRC	US Nuclear Regulatory Commission
NNSA	China National Nuclear Security Administration
NRW	Natural Resources Wales
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation
PAMs	Post-Accident Monitoring System
PARs	Passive Autocatalytic Recombiners
PCCWST	Passive Containment Cooling Water Storage Tank
PCCAWST	Passive Containment Cooling Ancillary Water Storage Tank
PCS	Passive Containment Cooling System

PCSR	Pre-Construction Safety Report
pga	Peak ground acceleration
PID	Project Initiation Document
PMS	Protection and Safety Monitoring System
PSA	Probabilistic Safety Assessment
PSHA	Probabilistic Seismic Hazard Analysis
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor
PXS	Passive Core Cooling System
RCS	Reactor Coolant System
RGP	Relevant Good Practice
RNS	Normal Residual Heat Removal System
RO	Regulatory Observation
ROA	Regulatory Observation Action
RP	Requesting Party
RQ	Regulatory Query
RSR	Remote Shutdown Room
SAMG	Severe Accident Management Guidelines
SAPs	Safety Assessment Principles
SBERG	Symptom-Based Emergency Response Guidelines
SBO	Station Black Out
SC	Seismic Category
SFP	Spent Fuel Pool
SSC	System, Structure and Component
SSE	Safe Shutdown Earthquake
STF	Stress Test Finding
TAG	(Nuclear Directorate) Technical Assessment Guide
TSC	Technical Support Contractor
UHS	Ultimate Heat Sink
UKP	UK Plant
VAS	Radiologically Controlled Area Ventilation System
WANO	World Association of Nuclear Operators
Westinghouse	Westinghouse Electric Company LLC
WENRA	Western European Nuclear Regulators Association
WWS	Waste Water System

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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. At that point, it received an Interim Design Acceptance Confirmation (IDAC) which had 51 GDA issues attached to it. These issues require resolution prior to the granting of a Design Acceptance Confirmation (DAC). This in turn is needed before any nuclear safety-related construction can begin on site. In August 2014 Westinghouse recommenced GDA of the **AP1000** design and began a programme to resolve the 51 issues.

2. The related GDA Step 4 report is the **AP1000** Cross-Cutting Topics Assessment Report (Ref. 1). It is published on the Office for Nuclear Regulation (ONR) website (www.onr.org.uk/new-reactors/assessment.htm), and 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).

3. GDA Issue GI-AP1000-CC-03 was raised following the earthquake and tsunami which severely damaged the Fukushima Dai-ichi and Dai-ni nuclear power plants in Japan in March 2011. Due to the timing of the Fukushima event during Step 4 of the **AP1000** design, the scope of the GDA to achieve IDAC was not extended to include lessons learnt from the event. It was instead judged appropriate to include such considerations in the scope of the GDA close-out and final DAC. This is because at the time of the issue of the **AP1000** IDAC a mature understanding of the Fukushima event and the associated lessons were not available. As the understanding of the event has improved, so Westinghouse's response and ONR's expectations have matured to allow response and assessment respectively.

4. The size and implications of the Fukushima event and the importance of lessons learnt were such that their consideration is required for all nuclear licensed facilities. The completion of GDA and granting of a DAC is therefore dependent upon the satisfactory demonstration of the implementation of lessons learnt from the Fukushima event.

5. This report is the ONR and Environment Agency's (EA's) cross-cutting assessment of the Westinghouse **AP1000** reactor design in light of post-Fukushima lessons learnt. Specifically, this report addresses one GDA issue as follows:

   - GI-AP1000-CC-03: Consider and action plans to address the lessons learnt from the Fukushima event.

6. GDA Issue GI-AP1000-CC-03 was raised as a cross-cutting issue as it affects a number of technical areas. The issue requires Westinghouse to demonstrate how it would take account of the lessons learnt from the events at Fukushima. The issue consists of two actions:

   - GI-AP1000-CC-03.A1: Westinghouse to address the lessons learnt from its internal review following the Fukushima event relevant to GDA for the **AP1000** plant.
   - GI-AP1000-CC-03.A2: Westinghouse to address the lessons learnt that are relevant to GDA for the plant from HM Chief Inspector's interim and final reports (Refs 2 and 3).

7. The EA has provided limited input to the assessment, which has been led by ONR due to the issue primarily concerning nuclear safety. Section 5 of this report presents the environmental regulators' input.

8. Assessment has been undertaken in accordance with ONR guidance (Refs 4, 5 and 6) as well as international regulatory guidance (Refs 7 and 8).

1.2 Scope

9. The scope of this assessment is detailed in the assessment plan (Ref. 9).

10. The scope of assessment focused on Westinghouse's understanding of the lessons learnt from Fukushima, the applicability of the lessons learnt to the **AP1000** design, and the identification and screening of potential design enhancements as a result of the lessons learnt. The scope of work was determined by considering the requirements of the GDA issue and Westinghouse's resolution plan (Ref. 10). The focus was Westinghouse's assessment of the **AP1000** design resilience to beyond design basis (BDB) events, along with the potential modifications to the design identified and the consideration and sentencing of the modifications. The assessment scope (Ref. 11) considered experience gained from the assessment of a similar GDA issue for the European Pressurised-water Reactor (EPR) design and the response to the Fukushima event by licensees.

11. The scope of assessment is appropriate for GDA because it focuses on the understanding of the lessons from the Fukushima event relevant to the **AP1000** design and the safety improvements to be adopted as a result. Unlike at an operating nuclear facility, site- and operator-specific aspects cannot be completely addressed in GDA. These aspects include such items as site location, geography and topology, return period considered in the design basis for extreme events, site-specific emergency response facilities, and site-specific flooding protection measures. These aspects will be for a future licensee to take forward in its site-specific safety cases.

12. GDA Step 4 assessed the adequacy of the **AP1000** design across many disciplines such as fault studies, probabilistic safety assessment (PSA) and external hazards. The conclusions reached by those assessments already provide insights into the resilience of the **AP1000** plant to events like that at Fukushima. This assessment has not attempted to repeat these Step 4 assessments. Instead, it has focused on the adequacy of Westinghouse's response to the GDA issue in accordance with the agreed resolution plan (Ref. 10). It is therefore recommended that this report be read in conjunction with the Step 4 assessment of the **AP1000** design and the close-out reports for the other GDA issues.

13. GDA Step 4 represents a detailed assessment of the **AP1000** plant against the ONR Safety Assessment Principles (SAPs) that were extant at the time. Following Fukushima and the end of GDA Step 4, ONR updated the SAPs. The introduction to the 2014 SAPs says: "This 2014 revision of the SAPs was prompted by publication in 2011 of the Chief Nuclear Inspector's report on the implications of the Fukushima accident for the UK nuclear industry. That report concluded that there were no significant gaps in the 2006 SAPs, but recommended a review to ensure that lessons learnt were incorporated. That review is now complete and this document contains the results." (Ref. 5).

14. For GI-AP1000-CC-03.A1, Westinghouse has used the European Nuclear Safety Regulators Group (ENSREG) stress test as an appropriate tool by which to present the results of the **AP1000** design evaluation. Westinghouse's approach has therefore focused on the challenges established by the stress test as described in Section 3 of this assessment report. I have assessed Westinghouse's response against the relevant 2014 modifications to the ONR SAPs resulting from ONR's own review of post-Fukushima lessons learnt. I have also assessed the response against the findings from the national UK stress tests report (Ref. 12). For GI-AP1000-CC-03.A2,

Westinghouse's approach and my assessment focus on the recommendations from the HM Chief Inspector's interim and final reports (Refs 2 and 3).

1.3 Methodology

15. The methodology for the assessment complies with internal guidance on mechanics of assessment within the ONR (Ref. 6).

1.4 Sampling Strategy

16. It is rarely possible or necessary to assess a safety submission in its entirety, and therefore ONR adopts an assessment strategy of sampling. A combination of two different assessment methods was used, 1) broad review and 2) deep-dive assessment. A broad review provides an overview of the submissions. I undertook a deep-dive assessment for those elements of the submissions of most relevance to my assessment scope, as described above. My assessment plan (Ref. 9) details the sampling strategy for this assessment.

2 ASSESSMENT STRATEGY

2.1 Pre-Construction Safety Report

17. ONR's GDA Guidance to Requesting Parties (RPs) (Ref. 13) states that the information required for GDA may be in the form of a Pre-Construction Safety Report (PCSR), and Technical Assessment Guide (TAG) 051 (Ref. 6) sets out regulatory expectations for a PCSR.

18. At the end of Step 4, ONR and the EA raised GDA Issue GI-AP1000-CC-03 (Ref. 14) 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.

19. All chapters of the **AP1000** PCSR have been revised from the draft version submitted in 2011 (Ref. 15). The technical content of relevance to GDA Issue GI-AP1000-CC-03 is contained in Chapter 12 of the revised PCSR. This report includes an assessment of the PCSR summary of post-Fukushima lessons learnt. It also verifies the adequacy of the line of sight between the PCSR summary and the underpinning GI-AP1000-CC-03 submissions. The version of Chapter 12 considered in this assessment is Rev 0C (Ref. 15).

2.2 Standards and Criteria

20. The relevant standards and criteria used during this assessment are principally the SAPs (Ref. 5), internal ONR TAGs (Ref. 6), relevant national and international standards and relevant good practice (RGP) informed from existing practices adopted on UK nuclear licensed sites. RGP, where applicable, has also been cited within the body of the assessment.

2.3 Safety Assessment Principles

21. The key SAPs applied within the assessment of Westinghouse's response to GI-AP1000-CC-03 are listed in Table 1 of this report.

22. The **AP1000** IDAC was issued following assessment against the previous (2006) version of the SAPs in Step 4 of GDA. Therefore, this assessment has considered the modifications to the 2014 SAPs resulting from lessons learnt from the Fukushima event. The SAPs listed in Part 1 of Table 1 contain significant changes relevant to GDA resulting from the ONR SAPs revision following the Fukushima event. A comprehensive list of the changes to the SAPs in the 2014 version and relevance to the Fukushima event is available on the ONR website (Ref. 5). The SAPs listed in Part 2 of Table 1 have not been modified significantly post-Fukushima but have also been referenced in my report. I have therefore listed them in the table for completeness.

2.3.1 Technical Assessment Guides

23. The TAGs that have been used as part of this assessment are set out below:

- NS-TAST-GD-005 Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable)
- NS-TAST-GD-013 External Hazards (Ref. 6)

2.3.2 National and International Standards and Guidance

24. The international standards and guidance that I have used as part of this assessment are set out below:

- ONR Report: Japanese Earthquake and Tsunami: Implications for the UK Nuclear Industry – Final Report (Ref. 2)
- ONR Report: European Council “Stress Tests” for UK Nuclear Power Plants, National Final Report (Ref. 12)
- European Nuclear Safety Regulators Group: Stress tests specification (Ref. 16)
- The International Atomic Energy Agency (IAEA): The Fukushima Daiichi Accident. Report by the Director General (Ref. 17)
- IAEA Safety Standards Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations, Specific Safety Guide No. SSG-18 (Ref. 8)
- Multinational Design Evaluation Programme (MDEP) Common Position on Fukushima (Ref. 18)

25. A large number of additional national and international standards and guidance documents have been updated to take into account post-Fukushima lessons learnt. These include the IAEA document SSR2/1 – Safety of Nuclear Power Plants: Design (Ref. 8), the IAEA International Fact-Finding Mission (Ref. 8) and the Western European Nuclear Regulators Association (WENRA) document “Safety of new NPP designs” (Ref. 19), along with guidance from the US Nuclear Regulatory Commission (NRC) and the Japanese Diet. My assessment did not explicitly use these documents . However, key updates to national and international standards and guidance are included as part of the wide-ranging reviews feeding into the standards and guidance that were used in this assessment (such as the updates to the 2014 SAPs and the IAEA Director General’s report). They have therefore also informed the assessment of this GDA issue, albeit indirectly.

2.4 Overseas Regulatory Interface

26. ONR’s strategy for working with overseas regulators is set out in its Strategic Plan (Ref. 20). In accordance with this strategy, ONR collaborates with overseas regulators, both bilaterally and multinationally. With particular significance to the closure of **AP1000** GDA issues, ONR is a member of the Organisation for Economic Co-operation and Development (OECD) facilitated MDEP **AP1000** reactor working group. MDEP is a multinational initiative undertaken by national safety authorities to develop innovative approaches to leverage the resources and knowledge of the national regulatory authorities tasked with the review of new reactor power plant designs. This helps to promote consistent nuclear safety assessment standards among different countries. At the **AP1000** working group biannual meetings, ONR and other nuclear safety regulators considering the **AP1000** design (notably US NRC and China National Nuclear Security Administration (NNSA)) share and discuss issues of common interest.

27. Following the events in Japan in 2011, the represented regulators on the MDEP **AP1000** working group have produced a common position paper on the applicability of lessons learnt from the Fukushima Dai-ichi accident to the **AP1000** plant (Ref. 18). ONR’s significant input to this common position has been informed by its assessment of Westinghouse’s submissions for GI-AP1000-CC-03, while cognisance of the shared position of the regulators of the MDEP **AP1000** working group has been used to inform ONR’s final judgements on the adequacy of Westinghouse’s submissions for GI-AP1000-CC-03.

28. The MDEP common position paper confirms that the regulators of the **AP1000** working group accept certain basic principles about the adequacy of the **AP1000** design with

respect to Fukushima. It states that the Fukushima Dai-ichi accident confirms the relevance of passive safety features that have been considered in the **AP1000** reactor design. The safety systems of the **AP1000** plant are designed and protected to tolerate external hazards, and the **AP1000** plant demonstrates that the design covers a wide range of extreme environmental conditions. The underlying strategies for coping with BDB conditions resulting from an extended loss of alternating current (AC) power and loss of access to the normal heat sink for **AP1000** plants involve a three-phase approach as follows:

- Initial coping through installed plant equipment without AC power or makeup to the passive containment cooling system (PCS). From 0 to 72 hours, the **AP1000** design includes passive systems that should provide core cooling, containment, and spent fuel pool (SFP) cooling.
- Following the 72-hour passive system coping time, support is necessary to continue passive system cooling. From three to seven days, installed plant ancillary equipment or off-site equipment installed to connections provided in the **AP1000** design should provide this support.
- To extend the passive system cooling time beyond seven days to an indefinite time, off-site assistance is necessary, such as the delivery of diesel fuel.

29. The MDEP common position paper concludes that the regulators of the **AP1000** working group recognise that these strategies are a fundamental part of the **AP1000** reactor design and are consistent with the Fukushima Dai-ichi accident lessons learnt. By providing multiple and diverse means of power and water supply to support key safety functions, these strategies can mitigate the consequences of BDB external events.

30. As part of ONR's work to develop the MDEP **AP1000** common position paper, I held a bilateral discussion with representatives from the NRC (Ref. 21). This discussion took place at an early stage of my assessment and enabled me to gain a more detailed understanding of the NRC's view of the **AP1000** post-Fukushima requirements than that set out in the MDEP common position paper. I note that my assessment is also fully consistent with the NRC's view as set out during the bilateral discussion.

2.5 Use of Technical Support Contractors

31. Technical Support Contractors (TSCs) were not used in the assessment of the Westinghouse response to GDA Issue GI-AP1000-CC-03.

2.6 Integration with Other Assessment Topics

32. 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. The assessment of GI-AP1000-CC-03 has been conducted on a cross-cutting basis.

33. The assessment was led by an external hazards specialist inspector. I also established formal interactions with specialist inspectors from a number of other technical areas to deliver the assessment of GI-AP1000-CC-03 in accordance with the assessment plan (Ref. 9).

34. These include:

- fault studies
- PSA
- internal hazards
- civil engineering
- human factors

- control and instrumentation (C&I)
- electrical engineering

35. Inspectors from these areas participated in early engagement on key issues. They assessed the sections of the Westinghouse post-Fukushima submissions relevant to their specialisms and provided written records of their assessments in the form of assessment notes (Refs 22, 23, 24, 25, 26, 27 and 28). These assessment notes were produced in accordance with HOW2 guide NS-TAST-GD-084 (Ref. 6) to underpin this close-out report.

36. Due to its cross-cutting nature, GI-AP1000-CC-03 has the potential to affect GDA issues in other technical areas. The relevant specialist inspectors have considered these interdependencies with other GDA issues as documented in their assessment notes.

2.7 Out of Scope Items

37. I agreed the following items with Westinghouse as being outside the scope of GDA:

- Site-specific elements of the **AP1000** design, including site-specific hazard derivations and emergency arrangements. ONR will assess these as part of any future site-specific activities.

3 REQUESTING PARTY DELIVERABLES IN RESPONSE TO THE GDA ISSUE

3.1 Deliverables

38. Westinghouse has provided two reports as deliverables to resolve GDA Issue GI-AP1000-CC-03:

- UKP-GW-GGR-201 UK **AP1000** Plant Post-Fukushima Assessment: documents the Westinghouse post-Fukushima response for the UK context (Ref. 29). This is Westinghouse's primary submission to address both actions of this GDA issue.

- UKP-GW-GL-109 Assessment of International Fukushima Lessons Learned Reports: documents the individual approaches, goals and safety enhancements that the various countries are taking to address Fukushima lessons learnt (Ref. 30). This is a supplementary submission to UKP-GW-GGR-201 to address international post-Fukushima lessons learnt.

39. Both deliverables are described in further detail below. Taken together, these deliverables are intended to address both actions associated with GDA Issue GI-AP1000-CC-03.A1: *Westinghouse to address the lessons learnt from their internal review following the Fukushima event relevant to GDA for the **AP1000** plant* and GI-AP1000-CC-03.A2: *Westinghouse to address the lessons learnt that are relevant to GDA for the **AP1000** plant from HM Chief Inspector Nuclear Installations' interim and final reports*.

3.2 Deliverable – UK AP1000 Plant Post-Fukushima Assessment UKP-GW-GGR-201

40. UK **AP1000** Plant Post-Fukushima Assessment (Ref. 29) is Westinghouse's primary submission in response to both GI-AP1000-CC-03.A1 and GI-AP1000-CC-03.A2. It presents the Westinghouse internal review of Fukushima lessons learnt and provides a response to the HM Chief Inspector's interim and final reports (Refs 2 and 3) and the stress test findings (STFs) (Ref. 12).

41. In response to GI-AP1000-CC-03.A1, Westinghouse's approach has focused on the challenges established by the ENSREG stress test. Following the events at Fukushima, the European Commission declared that "the safety of EU nuclear power plants should be reviewed on the basis of a comprehensive and transparent risk assessment" in the form of a "stress test". Driven by this recommendation, ENSREG developed the EU "Stress Test" specifications (Ref. 31).

42. Westinghouse's submission consists of an evaluation of the response of the **AP1000** plant when facing a set of extreme situations. It then describes the preventative and mitigating measures provided following a defence-in-depth logic – initiating events, consequential loss of safety functions, and severe accident management. For the assessment of these extreme situations, sequential loss of the lines of defence is assumed using a deterministic approach, irrespective of the probability of this loss. The assessment aims to identify whether there are any potential vulnerabilities for the considered extreme events in order to verify the robustness of the plant's defence-in-depth design, to provide an evaluation of margins against assumed reference levels to explore the possibility of cliff-edge effects, and to identify whether there are any reasonably practical enhancements that could provide potential margin improvements.

43. The Westinghouse submissions focus on the impact of such extreme events relative to maintaining the key plant safety functions of core cooling, containment integrity and SFP cooling. The focus of the technical scope of the **AP1000** plant assessment is placed on the following issues:

44. Initiating events:

- earthquake
- flooding (not limited to a tsunami)
- combination of both
- other potential limiting external hazards

45. Consequences of loss of safety functions from initiating events considered in the standard plant design:

- loss of all electrical power, including Station Black Out (SBO) and loss of DC power
- loss of ultimate heat sink (LUHS)
- combination of both

46. Severe accident management issues:

- means to protect from and to manage loss of core cooling functions
- means to protect from and to manage loss of cooling functions in the SFP
- means to protect containment integrity

47. In response to GI-AP1000-CC-03.A2, Westinghouse has provided a response for each of the applicable recommendations contained in the HM Chief Inspector's interim and final reports.

48. In summary, for both GI-AP1000-CC-03.A1 and GI-AP1000-CC-03.A2, the report includes:

- identification of relevant lessons
- consideration of their impact on the **AP1000** design
- identification of potential modifications
- sentencing of modifications
- final consolidated design in light of the lessons learnt from the Fukushima event

49. Westinghouse states in its submission that the **AP1000** plant design and its passive features have been developed considering catastrophic events which may lead to a complete and extended loss of power and infrastructure damage limiting site accessibility. Therefore the **AP1000** plant design is very robust against these types of events, and the detailed post-Fukushima assessment demonstrates this. For new-build projects in the UK, Westinghouse has identified five design changes that provide additional margin against extreme BDB events. These design changes are not required to meet safety goals, but they do provide enhanced coping capabilities and support plant operations following such BDB events. The report presents those modifications to the standard design which it considers reasonably practicable to implement as part of GDA, in light of the lessons learnt from Fukushima.

50. Westinghouse considers that it has made all reasonably practicable design changes to reduce risks as appropriate for GDA following the application of the lessons learnt from the Fukushima event. The reference design for GDA close-out includes the relevant approved Design Change Proposals (DCP) resulting from the GI-AP1000-CC-03 response. These are AP-GW-GEE-5252, 5261 and 5264 (Ref. 32), as listed in Table 3.

3.3 Deliverable – Assessment of Fukushima International Lessons Learned Reports UKP-GW-GL-109

51. The Westinghouse deliverable "Assessment of Fukushima International Lessons Learned Reports" (Ref. 30) presents the response of the **AP1000** design to lessons learnt from the Fukushima event around the world. This report includes consideration

of design modifications made to the **AP1000** design where it is being constructed or assessed in other regulatory regimes in China and the US.

52. The report gathers the individual approaches, goals and safety enhancements that the various countries are taking, or have previously taken, that address Fukushima event lessons learnt. Westinghouse developed a harmonised list from these inputs that define a global standard of Fukushima safety enhancements. This document provides a snapshot in time of the lessons learnt from the Fukushima event.

53. The report focuses on the international response from national regulators and international bodies. It considers the response to the Fukushima event in countries where the **AP1000** design is planned or in construction and applies the lessons learnt to the **AP1000** reactor design.

3.4 Deliverable – PCSR Updates

54. Chapter 12 of the **AP1000** PCSR provides a description of how Westinghouse addressed external hazards for the generic **AP1000** design. Westinghouse has now added a post-Fukushima assessment subsection to Chapter 12 of the PCSR as Appendix 12B (Ref. 15). This subsection describes the events at Fukushima and summarises Westinghouse's response to GDA Issue GI-AP1000-CC-03.

4 ONR ASSESSMENT OF GDA ISSUE GI-AP1000-CC-03

55. GI-AP1000-CC-03 is a joint GDA issue between ONR and the EA. ONR led the assessment due to the issue primarily concerning nuclear safety, and ONR's assessment is presented in this section of the report.

56. This assessment has been carried out in accordance with HOW2 guide NS-PER-GD-014, "Purpose and Scope of Permissioning" (Ref. 4).

57. My assessment is divided into the following topics which, taken together, address both actions that make up GDA Issue GI-AP1000-CC-03:

- Assessment of Lessons Learnt from Westinghouse Internal Reviews Following Fukushima (GI-AP1000-CC-03.A1)
- Assessment of Westinghouse's Report on International Lessons Learnt (GI-AP1000-CC-03.A1)
- Assessment of Lessons Learnt from the HM Chief Inspector's Interim Recommendations (IRs), Final Recommendations (FRs) (GI-AP1000-CC-03.A2) and Stress Test Findings (STFs) (GI-AP1000-CC-03.A1)
- Assessment of Westinghouse's Review of Potential Resilience Enhancements Derived from the Application of Lessons Learnt (GI-AP1000-CC-03.A1 and GI-AP1000-CC-03.A2)
- Relevant PCSR Updates

58. In accordance with the topic assessment plan (Ref. 9), I have used ONR specialist assessment resources in completing my review of Westinghouse's deliverables in response to this GDA issue. These inputs are recorded in the assessment notes referenced from this close-out report (Refs. 22, 23, 24, 25, 26, 27 and 28) and are summarised in the appropriate sections within this report.

4.1 Assessment of Lessons Learnt from Westinghouse's Internal Reviews Following Fukushima (GI-AP1000-CC-03.A1)

59. This section of the report presents my assessment of the internal reviews of the **AP1000** design robustness undertaken by Westinghouse in accordance with the resolution plan for GI-AP1000-CC-03.A1.

4.1.1 Review of AP1000 Design Against BDB Seismic Event

60. Westinghouse has provided a clear description of its seismic margins analysis, which demonstrates the **AP1000 design**'s SC-I (Seismic Category I) structures' robustness against a BDB earthquake. The analysis relies on two major tasks:

- the PSA-based model
- the determination of plant structure and component HCLPFs (high confidence of low probability of failure) up to at least 1.67 times the safe shutdown earthquake (SSE) level which is 0.3 g pga. High confidence is taken to mean greater than 95 percent and low probability is taken to mean less than 5 percent.

61. In my view, the methodology used is in line with relevant good practice. The analysis demonstrates that all structures and components required to maintain the plant in a safe, stable state are expected to function following a 0.5 g peak ground acceleration (pga) seismic event. The conclusion is that the **AP1000** plant design provides significant seismic margin with regard to maintaining the three fission product barriers (the fuel cladding, reactor coolant system (RCS) and containment) between the fuel in the core and the environment in accordance with SAP EHA.18 on BDB events.

62. The seismic margins assessment does not take credit for any operator actions. I acknowledge the conservatism in the seismic margins assessment of no operator actions, which reflects the design provision of passive systems included in the **AP1000** plant.

63. Westinghouse's response also considers SC-II (Seismic Category II) structures. These structures are designed so that they will not cause unacceptable structural interaction leading to failure of SC-I System, Structure and Components (SSCs). This is in line with ONR SAP ELO.4 paragraph 206, which states that any interactions between a failed SSC and other SSCs should be minimised.

64. As part of my assessment, I submitted a Regulatory Query (RQ) (Ref. 33) requesting further clarification on a number of matters related to my assessment of the **AP1000** plant's response to BDB seismic events. While the equipment required to cope with the event is provided as part of the **AP1000** fault schedule, I requested further information regarding the additional equipment that would be required post-72 hours. Westinghouse responded that only limited equipment is needed from off site post-72 hours (four small pumps, two small diesel generators (DGs) and several fans). In addition, material needed to connect these components to the plant would also be required from off-site such as cables and piping. Westinghouse states that the future site licensee would be responsible for ensuring that this equipment can be brought to site to cope post 72 hours, and I agree with this view. The only post-72 hour SSCs that require seismic qualification are the connection points for the off-site equipment.

65. As part of the above RQ, I questioned whether the SC-II ancillary equipment should be seismically qualified in accordance with ONR SAP EQU.1, which states that equipment should be "qualified to perform its allocated safety function in all relevant operational, environmental, fault and accident conditions". Westinghouse's response was that this is not required, as the installed ancillary SSCs are not credited in the safety case to provide the post-72 hour support. In my view, given the reliance on passive SC-I systems within 72 hours and the off-site equipment post-72 hours, this response is adequate.

66. The civil engineering inspector and I raised an RQ (Ref. 34) regarding the ductility of the 12 mm plate and resistance to concrete cracking in the SFP. In its response to the query, Westinghouse states that a ductile pool liner system is provided by welding the plate sections using full strength welds. The leak chases at the welds will intercept and direct any leakage at the welds away from the cracked concrete in accordance with SAP ECE.1. In addition, Westinghouse has stated that the pool liner will behave elastically under seismic load, and therefore ductility is not required. I judge this to be a reasonable approach and on this basis it is accepted.

67. The civil engineering inspector and I also queried the sloshing in the SFP (Ref. 34) in order to examine the possibility of damage to safety critical plant due to water spillage. Westinghouse has not calculated the sloshing heights during seismic action nor quantified the water losses, but claims that water losses due to sloshing are bounded by other events, notably pipe breaks. Westinghouse also claims that there are established pathways to collect and disperse water leaks due to the other events. Therefore safety critical plant would not be threatened by water spillage. Westinghouse has not discounted the effects of sloshing from the SFP by calculation. Instead, Westinghouse argues that the water spill due to sloshing will be bounded by other spills in the relevant plant areas that are directed to the auxiliary building sump. The civil engineering inspector and I consider this to be a reasonable approach and that it is disproportionate to insist that Westinghouse quantifies the spill volume by calculation for the relatively small **AP1000** SFP. On this basis, Westinghouse's response is accepted (Ref. 27).

68. In my view, Westinghouse's analysis of post-Fukushima lessons learnt as relevant to beyond design basis seismic events is adequate for GDA. However it is important to note that the assessment of the seismic hazard is necessarily limited at GDA stage as the site-specific seismic hazard assessment details are not known. At the site-specific phase, and as part of normal business, a future licensee will be required to perform a seismic hazard assessment to demonstrate that the site-specific seismic hazard is bounded by the generic site envelope with no cliff-edge effects beyond the design basis. A future licensee will also be required to perform an analysis to determine whether any further reasonably practicable resilience enhancements should be provided to ensure that risks are reduced ALARP.

4.1.2 Review of AP1000 Design Against BDB Flooding Event

69. A design basis for external flooding and the corresponding BDB margins can only be defined and assessed at the site-specific phase. This is because it is only at the site-specific phase that the platform height is known and the site flood hazard frequencies have been assessed. Therefore, to address BDB flooding at the GDA stage, my expectation was for Westinghouse to set a generically defined reference elevation in relation to the plant design and then consider vulnerabilities to flooding beyond this reference elevation. Margins can then be evaluated by considering the freeboard (ie the difference between the reference elevation and the water level at which a vulnerability has been revealed). This analysis provides an indication as to where cliff-edge effects beyond the reference elevation exist in accordance with SAPs EHA.7 and FA.7. Westinghouse has performed this analysis and the results are clearly set out within its submission.

70. Westinghouse has chosen to define a generic site in accordance with the "dry site concept". In this case, all vulnerable SSCs are located above the level of the design basis flood. I consider this to be adequate in line with the revised text of SAP EHA.12.

71. Westinghouse has taken a conservative approach to the assessment of external flooding within GDA. In its submission, Westinghouse considers a gradual but sustained BDB flooding event that could be caused by coastal or river flooding. Westinghouse has also examined potential vulnerabilities to a rapid flood that might occur due to a dam breach or a tsunami in accordance with the guidance in the IAEA safety standard SSG-18 (Ref. 8). In its submission, Westinghouse has considered the hydrodynamic loading that could occur due to a rapid flood and its potential effects on structures in accordance with SAP ECE.6, particularly water tanks that could be displaced due to buoyancy effects. Although I consider that a gradual but sustained BDB flood is more applicable to the UK context, I welcome Westinghouse's additional consideration of a rapid flood in its analysis of post-Fukushima lessons learnt.

72. ONR SAP EHA.7 paragraph 248 has been added to take into account post-Fukushima lessons learnt. The revised SAP states that the analysis should identify the margins BDB to the point(s) where safety functions would no longer be achieved, as a function of increasing hazard severity. Westinghouse's submission provides a clear examination of the sequential loss of lines of defence in case of a BDB external flooding event. Due to the generic nature of the assessment, Westinghouse modelled these losses deterministically without taking into account the sequence frequency.

73. As a result of this margins assessment, Westinghouse concluded that, in a BDB external flood of up to 5.3 metres above grade level, containment and core cooling would not be adversely impacted for 72 hours post-accident in all refuelling and power operating modes. In power operating scenarios, cooling of the fuel in the SFP will be maintained with no requirement for makeup. During refuelling, the SFP would require makeup. This would be available either through valves from the Passive Containment

Cooling Water Storage Tank (PCCWST*) to the SFP or via portable pumps and flexible piping.

74. As a result of this examination of potential vulnerabilities to external flooding, Westinghouse has proposed a number of design changes that will increase the **AP1000**'s resilience against BDB external flooding. In my view, these design changes reflect relevant good practice as discussed in Section 4.4 of this report.

75. The C&I inspector and I requested (Ref. 35) further information from Westinghouse regarding the seismic qualification of the remote diverse actuation system (DAS). This is because in Westinghouse's submission the loss of the main control room (MCR) is considered as a potential event following a BDB flood and the DAS panel is credited in these instances. The DAS is a diverse system that provides an alternative means of initiating reactor trip, actuating selected essential safety functions, and providing plant information to the operator. According to information currently available (Refs 36 and 37), the DAS is not seismically qualified for operation at the SSE level of 0.3 g pga. Therefore, there could be a lack of adequate displays and controls in case of a BDB flood followed by a relatively minor seismic event (of a magnitude below the SSE). Considering the potential loss of the MCR (due to BDB flooding) and of the remote DAS panel (due to a seismic event), the C&I inspector and I asked Westinghouse to clarify which means of displays and controls would remain available. Westinghouse's response (Ref. 35) referred to the additional flood protection proposed for the UK **AP1000** plant, as described in Section 4.5.2 of this report. With this design enhancement, the MCR and remote shutdown room (RSR) will not be lost due to a BDB flood. This design enhancement provided additional confidence and the C&I inspector and I accept the response as adequate.

76. In my view, Westinghouse's analysis of post-Fukushima lessons learnt is adequate for GDA, although it is important to note that the assessment of external flooding within GDA is necessarily limited by the fact that site-specific details are not known. A future licensee will be required to perform further assessment as part of normal business to verify that the intended site meets the requirements of the dry site concept, and to determine whether it should provide further reasonably practicable resilience enhancements to ensure that risks are reduced ALARP.

4.1.3 Review of AP1000 Design Against Loss of Electrical Power

77. The design philosophy of the **AP1000** plant is to place no claims on AC power for delivering key safety functions for 72 hours following any design basis or BDB event. This was subject to ONR assessment in Steps 3 and 4 in a number of disciplines and was largely accepted, with some aspects having been carried forward as part of the GDA issue closure work, including issues FS-06, EE-01, PSA-01 (Ref. 38). The design philosophy does make claims on protecting direct current (DC) power and on the need for limited AC power after 72 hours. ONR accepted the **AP1000** design philosophy in response to the loss of electrical power as part of the GDA Step 4 assessment. My assessment has focused on ensuring that the lessons learnt post-Fukushima do not undermine the conclusions reached in Step 4.

78. ONR SAP EES.9 states that "Essential services should be designed so that the simultaneous loss of both normal and back-up services will not lead to unacceptable consequences". This SAP was enhanced post-Fukushima with the addition of the explanatory text in paragraph 442 which states that the safety case should analyse such loss of service events and demonstrate the continuing safety of the facility.

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* *The PCCWST is an annular tank located around the air exhaust on top of the shield building. It has an approximate minimum volume of 3,501 m^3.*

79. The Westinghouse response provides assurance that the **AP1000** plant can cope with the loss of normal and back-up power. The response states that the **AP1000** plant is designed so that an external power supply is not credited in the event of a design basis or BDB flood. If all AC and DC power are lost, the reactor will trip automatically (if it has not already been tripped manually). The passive core and containment cooling systems will actuate automatically on the loss of DC power and certain isolation valves will fail open. Once actuated, the passive cooling systems will maintain reactor cooling for several days.

80. In line with the new EES.9 explanatory paragraph, Westinghouse's submission shows that there would be sufficient time available to restore the service before unacceptable consequences could arise. The **AP1000** plant's passive safety systems offer a grace period of 72 hours following an SBO event. Post-72 hour requirements will vary depending on whether the ancillary equipment is available.

81. The Westinghouse submission also justifies how further back-ups will be brought into service to meet the safety demand in line with the relevant SAPs revision. Westinghouse recommends that for each **AP1000** unit, a future licensee should have at least two locations where it can obtain small portable electrical generators and self-powered pumps from off-site. Although obtaining storing, and retrieving this mobile equipment is the responsibility of a future licensee, Westinghouse does provide provisions for the connection and use of the equipment in the generic design. Emergency arrangements are also the responsibility of the future licensee, but Westinghouse's submission states that it is recommended that training and drills be conducted to ensure that the equipment can be transported, connected and operated if required. In my view, this is approach is adequate in line with the requirements of GDA.

82. Westinghouse has performed a review to demonstrate that the likelihood and consequences of the event mean that it is not reasonably practicable to add further back-up provisions to the design. I examine this in Section 4.3 of this report.

83. In my view, Westinghouse's submission meets the intention of this revised SAP EES.9 and new explanatory paragraph. Westinghouse has provided adequate evidence that it has considered the post-Fukushima lessons learnt against the loss of electrical power for the **AP1000** design. This is also the view of the ONR fault studies (Ref. 23) and electrical engineering (Ref. 24) inspectors.

4.1.4 Loss of Ultimate Heat Sink Events

84. The Westinghouse submission clearly describes how the **AP1000** plant is designed to cope with LUHS events. For the **AP1000** plant, the ultimate heat sink (UHS) is the atmosphere. In terms of containment cooling, decay heat is transferred to the atmosphere by the PCS, which provides a passive cooling of the containment. For the **AP1000** SFP cooling, decay heat is removed by heating up and boiling off SFP water which is released to atmosphere via a vented path. The PCCWST provides water for containment cooling or SFP cooling for at least 72 hours.

85. The **AP1000** plant's response to LUHS was subject to ONR assessment in Step 4 of GDA, primarily within the fault studies discipline (Ref. 1). It was largely accepted, with limited aspects carried through to the GDA closure work (Ref. 38). It is not my intention to repeat that assessment here. My assessment has focused on ensuring that the lessons learnt post-Fukushima do not undermine the conclusions reached in Step 4.

86. ONR's heat transfer systems (EHT) SAPs have been clarified post-Fukushima to state that the safety case should consider the potential non-availability of external resources. In addition to this, SAP EKP.3 has been redrafted to emphasise the need for

independent defence-in-depth barriers to fault progression. In line with these requirements, the **AP1000** plant provides a number of additional on-site sources of cooling water that can be used in case the PCCWST is unavailable. These include the Passive Containment Cooling Ancillary Water Storage Tank (PCCAWST), PCS external makeup flange, fire protection system (FPS) tanks, demineralised water transfer and storage system (DWS) tanks, and other sources, all of which can provide cooling to the containment or the SFP. These sources are sufficient to extend the coping time to seven days without off-site support. I consider this adequate, in line with the lessons learnt post-Fukushima, as reflected in the SAPs.

87. It is important to recognise that the **AP1000** plant's reliance on passive systems is one of its major differences compared to currently operating pressurised water reactor (PWR) designs. These passive systems are designed to provide heat removal following extreme BDB events, as described above. Paragraph 151 of the SAPs on the hierarchy of safety systems places passive safety measures that do not rely on control systems, active safety systems or human intervention at the top of the hierarchy. Passive systems provide a certain degree of reassurance that unacceptable consequences will not be realised, and it is reasonable to credit the high reliability of these types of systems in my assessment of the **AP1000** plant's ability to cope with the LUHS.

88. Another post-Fukushima lesson learnt relevant to the LUHS relates to the SFP. If the UHS is lost, active cooling of the SFP will be lost. The **AP1000** SFP is designed so that the fuel is kept cool by the water heating up, boiling and turning to steam. This provides effective cooling as long as the fuel remains covered in water. This is assured for 72 hours. The EHT SAPs have been modified to state that bottom penetrations and lines that are prone to siphoning faults should be minimised in SFPs. The **AP1000** SFP piping connections were assessed by the fault studies discipline as part of GDA Step 4 and as part of the resolution of GDA Issue GI-AP1000-FS-01 (Ref. 1). Piping connections are limited in their potential to drain the SFP because they interface with the SFP through the transfer gates whose lowest elevation is above the top of the fuel. In my view, the SFP design meets the intention of the SAPs in terms of minimisation of SFP penetrations.

4.1.5 Review of AP1000 Design Severe Accident Management

89. The Westinghouse submission clearly describes the sequencing and function of cooling systems deployed during postulated severe accident management sequences. This includes the means to protect from and to manage loss of core cooling functions in the reactor and SFP, and means to protect containment integrity.

90. The information presented by Westinghouse in the current submission repeats that previously presented within the severe accidents and PSA disciplines and assessed as adequate during Step 4 (Ref. 1). Since then, several of ONR's SAPs related to severe accident management have been updated to reflect lessons learnt from the Fukushima event. I have assessed the Westinghouse submission against the revised SAPs. Fault studies, PSA, and human factors specialist inspectors have also assessed aspects of the Westinghouse submission on severe accident management relevant to their disciplines.

91. The fault studies specialist assessor judged the severe accident management section of the Westinghouse submission to be adequate for the purposes of GDA. The inspector did not raise any comments on this section of the report (Ref. 23).

92. The PSA specialist assessor noted (Ref. 25) that the current Level 2 PSA has been used to support the post-Fukushima assessment of severe accident management measures in the GI-AP1000-CC-03 submission. Westinghouse provided a Level 2 PSA

at GDA Step 4. This included an understanding of the risk from the external hazards of seismic events and flooding. Although the external events PSA is not being developed further during the GDA close-out phase, ONR has agreed with Westinghouse that the PSA will be developed during the licensing phase to include comprehensive coverage of external hazards. The current PSA includes BDB events and extended mission times. On this basis, the use of the current Level 2 PSA is considered adequate for the purposes of GDA.

93. The human factors specialist assessor provided feedback (Ref. 39) to Westinghouse on the submission requesting further details on a sample of two operator actions required to mitigate a design basis accident. The first action was for operators to provide makeup water to the SFP by gravity drain from the PCCWST. The second action was for operators to provide makeup to the PCCWST and SFP from the PCCAWST with the off-site pump. Both of these actions relate to the critical task of restoration of the heat sink to the reactor and SFP, and both are also considered as part of the close-out of GDA Issue GI-AP1000-HF01 (Ref. 40).

94. The human factors specialist assessed Westinghouse's response (Ref. 39) and judged it to be a reasonable substantiation of the human-based claims. The response did not provide details with regard to potential human errors and interactions with other operator actions. However, the analyses do provide a comprehensive set of claims, arguments and evidence, which summarise the findings of the analysis. In addition, the activities are demonstrated to be relatively simple and straightforward such as simple valve movements. Each of the analyses is underpinned by a comprehensive set of assumptions about the future licensee and these assumptions will need to be verified by the future licensee as part of normal business. Further details on the human factors assessment of these operator actions can be found in his assessment note for this GDA issue (Ref. 26) and in the assessment report of GDA Issue GI-AP1000-HF-01 (Ref. 40).

4.2 Assessment of Westinghouse's Report on International Lessons Learnt (GI-AP1000-CC-03.A1)

95. During early engagement discussions with Westinghouse I emphasised the need to incorporate international learning post-Fukushima into Westinghouse's proposed submission (Ref. 41). The intent was to gain clarity on how lessons learnt from other regulators and ongoing licensing and construction of the **AP1000** design were being captured in the UK-specific **AP1000** design. Westinghouse accepted this action and updated the resolution plan in response (Ref. 42). The updates included explicitly stating that the review would be comprehensive in nature and would include lessons learnt from other new reactor build projects internationally, including the **AP1000** reactor projects in China. When it was published, the lessons from IAEA Director General's report into the Fukushima Dai-ichi Accident (Ref. 17) were also added to the scope (Ref. 43).

96. Westinghouse produced a standalone report to respond to this action – Assessment of Fukushima Lessons Learned Reports (Ref. 30). My assessment of this deliverable considered the following aspects:

- Examination of the adequacy of the inputs considered for the international lessons learnt
- Assessment of the Westinghouse response to the lessons learnt
- Integration of Westinghouse response to these lessons learnt into the overall response to GI-AP1000-CC-03

97. The report is viewed as supplementary to UK **AP1000** Plant Post-Fukushima Assessment (Ref. 29). It provides completeness to the potential lessons learnt from the

Fukushima event, in considering lessons not identified in the ONR response to Fukushima (Ref. 2) and **AP1000** design experience gained in other regulatory regimes.

4.2.1 Examination of the Adequacy of the Inputs Considered for International Lessons Learnt

98. The extraction and examination of lessons learnt from the Fukushima event has been conducted with a large degree of international co-operation. There is therefore a high degree of consistency between the regulatory responses to the event. The primary sources of information on the Fukushima event originate with the Japanese responsible parties and IAEA. With common sources of information, it is understandable that common themes emerge in the lessons learnt identified by different bodies. The approach adopted by regulatory bodies differs, with most regulators applying a stress test approach and the NRC applying its own established requirements.

99. Westinghouse considered input from the following countries to identify the international lessons learnt relevant to the **AP1000** design:

- Belgium
- Brazil
- Canada
- China
- Czech Republic
- France
- Germany
- Japan
- Korea
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- Taiwan
- United Kingdom
- United States of America

100. Westinghouse also considered input from the following international organisations to identify the international lessons learnt relevant to the **AP1000** design:

- IAEA
- WENRA
- WANO (World Association of Nuclear Operators)
- INPO (Institute of Nuclear Plant Operations)

101. I consider this to be a suitable list of countries and international organisations from which to draw lessons learnt. It includes both regulatory and operational bodies. As the lessons learnt from the Fukushima event are embedded into guidance the available publications will increase in number, but the understanding of the Fukushima event is sufficiently well developed to expect that the major lessons have been identified.

102. My assessment concludes that the inputs considered for lessons learnt are adequate within GI-AP1000-CC-03.

4.2.2 Assessment of the Westinghouse Response to International Lessons Learnt

103. Westinghouse collated the lessons learnt from the national responses to the Fukushima event of the countries and organisations identified above. The lessons

have been grouped by country and by safety area in Appendices A and B of the report (Ref. 30) respectively. A harmonised list of global lessons learnt is presented as Appendix C of the report (Ref. 30), with responses grouped to identify common themes. This is intended to enable Westinghouse to provide broad responses to lessons learnt.

104. Global lessons learnt are categorised as:

- seismic
- flooding
- other external events
- SFP
- severe accident management
- emergency planning
- extended loss of AC power
- UHS
- generic

105. I have assessed the listing and grouping of lessons learnt by sampling. The lessons learnt selected are those relevant to GI-AP1000-CC-03 within the selected sample. The approach adopted by Westinghouse is considered consistent with the intent of GI-AP1000-CC-03 and in accordance with the approach and scope discussed during the development of Westinghouse's response.

106. Westinghouse presents the response to lessons learnt in the body of the Assessment of Fukushima Lessons Learned Reports (Ref. 30). In response to each of the categories of lessons learnt Westinghouse analysed the lessons learnt and provided a description of the **AP1000** plant's design response.

107. I judge the report to accurately collate and summarise the lessons learnt from the selected regulatory regimes.

108. Westinghouse has assumed for the purposes of GDA that **AP1000** reactor operators will respond to an extreme event with an approach based on the "FLEX[†]" strategy adopted by US utilities. The approach to emergency arrangements which is adopted by a future licensee of **AP1000** design nuclear power stations will be the responsibility of the licensee; its options are not restricted by the conclusions of this report. ONR does not define the approach to emergency arrangements that licensees should adopt.

109. The intent in requesting that Westinghouse demonstrably considers international lessons learnt was to identify any lessons in addition to those from the Westinghouse internal review and the ONR lessons learnt exercises. Any additional lessons learnt would then feed into the consideration of safety enhancements for the UK **AP1000** design. No additional lessons were identified through the international lessons learnt review. This is reassuring, as in my view the exercise has provided a useful cross-check to ensure that all relevant lessons learnt have been captured within Westinghouse's response.

4.3 Assessment of Lessons Learnt from the HM Chief Inspector's Interim Recommendations (IRs), Final Recommendations (FRs) (GI-AP1000-CC-03.A2) and Stress Test Findings (STFs)

110. Following the earthquake and tsunami which severely damaged the Fukushima Dai-ichi and Dai-ni nuclear power plants in Japan in March 2011, ONR's HM Chief Inspector produced a set of reports for the UK Government on the events at

[†] FLEX is a strategy developed by the nuclear energy industry to implement the NRC's Fukushima task force recommendations quickly and effectively. The strategy is "flexible" in that it relies on portable equipment to respond to BDB events.

Fukushima (Refs 2 and 3). The reports made a number of FRs and IRs to ensure appropriate lessons were learnt and implemented from the Fukushima event by nuclear operators globally. Nuclear operators across Europe were also tasked with responding to the STFs generated from a separate EU review of the Fukushima event (Ref. 12).

111. The intent of GI-AP1000-CC-03.A2 was to ensure that Westinghouse has adequately captured and responded to the lessons learnt from the HM Chief Inspector's IRs and FRs (Refs 2 and 3). I also asked Westinghouse to provide a response to ONR's STFs. Westinghouse was then required to take these lessons into account as appropriate for the **AP1000** design. Table 2 includes the complete list of IRs, FRs and STFs for GI-AP1000-CC-03.A2, a summary of Westinghouse's response and a description of my assessment.

112. I began my assessment by considering whether Westinghouse had identified all IRs, FRs and STFs that were relevant to **AP1000** design and should be considered within the scope of GDA. In my view, Westinghouse identified and addressed all lessons learnt that I consider relevant to the **AP1000** design within the scope of GDA. I also found that Westinghouse had addressed at least partially some lessons learnt which were outside the scope of the **AP1000** design in GDA. While this may be beyond the intent of GI-AP1000-CC-03.A2, it provides guidance to a future licensee to facilitate its response to the lessons learnt. The consideration of these lessons learnt does not alter the scope of the GDA and will not alter ONR's expectations on a future licensee seeking to license an **AP1000** plant.

113. I assessed Westinghouse's response to the IRs, FRs, and STFs with input from appropriate specialist assessors. Regulatory Queries (RQs) were raised if required. Assessors recorded their assessment in assessment response sheets. Table 2 contains details of the assessments and reference to the assessment response sheets.

114. I consider all of the Westinghouse responses to lessons learnt to be adequate following the resolution of the RQs raised during the assessment. I have not raised any assessment findings (AFs) in response to the Westinghouse resolution of GI-AP1000-CC-03.A2.

4.4 Assessment of Westinghouse's Review of Potential Resilience Enhancements from the Application of Lessons Learnt (GI-AP1000-CC-03.A1 and GI-AP1000-CC-03.A2)

115. This section of the report concerns my assessment of Westinghouse's analysis of potential resilience enhancements that could be applied to the **AP1000** design.

116. In the European Design Control Document (EDCD) submitted during Step 3 of GDA (Ref. 44) and the PCSR produced at the end of Step 4 (Ref. 45), Westinghouse claimed that the extant design could meet all relevant basic safety objectives (BSOs) and basic safety levels (BSLs) as set out in ONR's SAPs. The **AP1000** plant was developed taking into account potential catastrophic events, and a detailed assessment of the robustness of the design has been carried out in previous steps of GDA. The lessons learnt from Fukushima do not undermine the conclusions reached. However, reviewing lessons learnt and identifying reasonably practicable resilience enhancements emerging from these reviews are important elements of nuclear safety culture. ONR's SAPs paragraphs 698 and 701 indicate that it is necessary to consider whether it is reasonably practicable to reduce risks further. Therefore, I welcome Westinghouse's reviews in this area.

117. Although it has been possible for Westinghouse to identify reasonably practicable resilience enhancements for the **AP1000** design, it is important to note that there are certain constraints on performing a full ALARP assessment as part of GDA. ONR's "Guidance to Requesting Parties" (Ref. 13) states that to ensure a meaningful GDA has been performed, a "thorough and detailed assessment" is required. A thorough and detailed assessment means that "ONR has looked in detail at the submissions and judged them against the SAPs, including the need to demonstrate that risks are reduced, or are capable of being reduced, ALARP". In the case of external hazards such as the initiating events that occurred at Fukushima, the lack of site-specific external hazard information at the GDA stage means that a full demonstration that risks are reduced ALARP cannot be provided. However, the starting point for demonstrating that risks are reduced ALARP and safety is adequate is that the normal requirements of good practice in engineering, operation and safety management are met. These normal requirements of good practice have evolved based on lessons learnt post-Fukushima. Therefore, a preliminary demonstration of ALARP and a consideration of reasonably practicable resilience enhancements can be performed as part of GDA based on comparison with RGP. At the site-specific phase, and as part of normal business, a future licensee will perform a further review to determine whether providing additional resilience enhancements is reasonably practicable to ensure that risks are reduced ALARP.

118. As a result of its own internal review of post-Fukushima lessons learnt and its review against the HM Chief Inspector's recommendations and findings, Westinghouse identified the following potential resilience enhancements, and came to the following conclusions as to whether it would be reasonably practicable to implement them at GDA stage (the enhancements selected for implementation are in bold type in the list below):

1. Filtered containment venting (FCV)
2. **BDB flood protection for Class 1 batteries**
3. Hydrogen mitigation (in containment and auxiliary building)
4. **Enhanced power supply for communication systems**
5. SFP makeup enhancement to reduce operator actions
6. SFP instrumentation enhancements
7. **Improved post-72 hour cable connections**
8. **Enhanced off-site equipment locations and connections**
9. Hardening of ancillary equipment
10. **Additional connections for on-site water storage tanks**
11. Hardening of Class 2 systems

119. In order to inform its decision, Westinghouse performed an analysis of each of the above potential resilience enhancements to determine whether each enhancement would be applied to the **AP1000** design. I reviewed the list of enhancements against the application of lessons learnt and in my view the list is wide ranging and complete. My assessment examines the process that Westinghouse undertook and the conclusions it reached for each potential enhancement. The objective of my assessment is to come to a view as to whether Westinghouse's process is adequate and its conclusions are reasonable, in line with my expectations for GDA.

4.4.1 Filtered Containment Venting

120. Following the events at Fukushima, many reviews have been done internationally and in the UK into the merits of FCV. These reviews are part of a wider post-Fukushima ambition to minimise large and early releases from containments. One example of these international efforts is the OECD report on FCV published in 2014 (Ref. 46). This document states that "the overarching goal of filtered containment venting is to prevent, in the event of a severe accident, overpressure failure of the containment and

keep the containment pressure below its design value while minimising radioactivity releases to the environment".

121. Consistent with the above, Westinghouse has undertaken its own review of whether it is reasonably practicable and beneficial to safety to add FCV to the **AP1000** plant. This review is summarised in its post-Fukushima submission.

122. Westinghouse has described the existing design provision for containment overpressure protection. The PCS primarily provides overpressure protection for the **AP1000** reactor containment boundary. If passive PCS water delivery fails completely, 24 hours' coping time to restore water cooling and multiple alternative pumped water sources are available. The **AP1000** plant includes features to promote in-vessel retention of core debris to minimise the likelihood of reactor vessel failure, molten core concrete interaction, and consequential ex-vessel flammable gas generation. In accordance with the requirements of SAP EPS.5, Westinghouse has also undertaken a review of the sequences in the PSA that result in a release in order to put the benefit of FCV into context.

123. Westinghouse concluded that it is not reasonably practicable to add FCV to the **AP1000** reactor design. This is based on the following:

- Venting can create a negative or back pressure in the containment which may lead to structural instabilities.
- The Level 2 PSA shows that the frequency of late containment releases for which FCV may be useful is very small ($< 10^{-8}$/year).
- If passive PCS water delivery to the containment shell is postulated to be failed, the containment provides approximately 24 hours' coping time to restore water cooling before exceeding American Society of Mechanical Engineers (ASME) service level C stresses. Multiple alternative pumped water sources are available to restore containment cooling.
- Containment venting does not address more likely containment failures due to containment bypass, containment isolation failure and high-energy severe accident phenomena that could occur in the course of a severe accident.
- In extremis, a vent pathway is provided through the Normal Residual Heat Removal System (RNS) suction line into the SFP to mitigate containment overpressure.
- In addition to the arguments presented in Westinghouse's submission, the MAAP5 analysis for the shutdown plant states shows that containment isolation is important for maintaining the conditions needed for natural heat loss mechanisms to function (Ref. 47). Adding FCV introduces an additional failure mode that could compromise this.

124. I have considered Westinghouse's review and have also consulted with the PSA specialist inspector (Ref. 25) and the fault studies inspector (Ref. 23).

125. The conclusion is that Westinghouse has performed an adequate review to determine whether to add FCV to the **AP1000** design for the UK context. Westinghouse has demonstrated that the **AP1000** plant manages containment pressure by means other than FCV following a severe accident. Westinghouse has identified severe accident challenges and has demonstrated that FCV is still not required as the nuclear safety benefits are very minor and there are also disadvantages. In the view of the PSA specialist inspector, large early releases tend to be dominated by containment bypass accidents for which a filtered containment vent would not provide a benefit. For the AP1000 plant, the addition of a filtered containment vent would actually provide an additional containment bypass route which could comprise the passive safety systems' functions. Therefore, I agree with Westinghouse that it is not reasonably practicable to add FCV to the **AP1000** design.

4.4.2 BDB Flood Protection for Class 1 IDS Batteries

126. Westinghouse has provided a clear description of the optioneering it performed to determine the efficacy of enhancing the protection of Class 1 batteries from a BDB flood. The protection of the Class 1 DC and uninterruptible power supply system (IDS) batteries against external flooding will allow the **AP1000** plant to better cope with a BDB flood. The Class 1 IDS batteries provide the Class 1 power source to the Class 1 systems. Protection of the batteries increases the likelihood that the post-accident monitoring system (PAMs) will be available to the operators to support plant monitoring following a BDB flood.

127. The design changes required include providing a watertight sealant for electrical penetrations, adding three watertight doors in the periphery of the auxiliary building, enhancing waste water system (WWS) drains to prevent backflow and enhancing the design of several additional penetrations to prevent water ingress.

128. Westinghouse determined that it could increase the protection of the Class 1 IDS batteries against external flooding for a moderate cost. On this basis, Westinghouse found the enhancement to be reasonably practicable. Therefore, Westinghouse identified the following DCP:

- APP-GW-GEE-5252 Changes to United Kingdom **AP1000** Plant (UKP) to increase the Protection of Class 1 Batteries from Beyond Design Basis Flood

129. The DCP has been approved for inclusion in the GDA design reference point (Ref. 32). On this basis, Westinghouse's consideration and endorsement of additional BDB flood protection for Class 1 batteries is accepted.

4.4.3 Hydrogen Mitigation (In Containment and Auxiliary Building)

130. Westinghouse states there are three main events that could result in hydrogen generation – all are severe accidents BDB. These are:

- A loss of coolant accident (LOCA) fault which results in the zirconium clad fuel in the core becoming uncovered and oxidising with steam to generate hydrogen.
- Failure of in-vessel retention of the core following a severe accident where the melted core (corium) melts the pressure vessel and falls onto the concrete below. Hot corium could react with concrete to generate hydrogen.
- A catastrophic drain-down of the SFP resulting in fuel becoming uncovered, heating up and oxidising with steam.

131. Westinghouse's description of alternative severe accident hydrogen mitigation strategies and corresponding potential design enhancements is clear. These include:

- low limestone concrete in the lower elevations of the containment vessel
- long-term power supplies for a limited number of igniters in containment
- additional passive autocatalytic recombiners (PARs) in containment
- adding PARs to the fuel handling building

132. Westinghouse's analysis of limestone and basaltic aggregate concrete types did not find a clear benefit from one type over another, and thus the decision not to specify low limestone concrete for the lower elevations of the containment vessel is accepted. Regarding the addition of PARs to the fuel handling building, Westinghouse's analysis found that flammability conditions were not mitigated by adding 10 PARs. Instead of the use of PARs, Westinghouse's analysis showed that venting from containment high pressure into the SFP, together with operation of the radiologically controlled area ventilation system (VAS), is sufficient to minimise the flammability of hydrogen in the

fuel handling building. I agree with this conclusion. Therefore, the decision not to add PARs to the fuel handling building is also accepted.

133. The fault studies inspector and I raised an RQ on hydrogen mitigation as part of RQ-AP1000-1478 concerning long-term power supplies for igniters and the provision of additional PARs in containment. This is because, based on my review of Westinghouse's first submission, I found that the argument for not extending the power supply to the ignitors or adding extra PARs was not convincing. In my view, the benefits were clearly described but it was not clear why the improvements were not adopted.

134. Westinghouse submitted its RQ response (Ref. 48) and, after further discussions with ONR, Westinghouse updated its submission to clarify the adequacy of the existing PARs. It completed an analysis which shows that additional PARs or extended igniter power would not provide further benefit for in-vessel scenarios. Benefits were only achieved in postulated low frequency scenarios in which coincidental LOCA and SBO events lead to early reactor vessel failure and molten core concrete interaction (MCCI) hydrogen generation. Westinghouse estimates that the frequency of these scenarios is less than 3×10^{-09} per reactor year, and the cost to mitigate against them is estimated to be more than $1 million. On this basis, Westinghouse concludes that the cost is grossly disproportionate to the benefits obtained.

135. I have considered this argument and accept the clarification provided. The fault studies inspector is content that Westinghouse has undertaken a thorough review of potential improvements to hydrogen mitigation in response to this GDA issue. He welcomes that consideration of ex-vessel and SFP scenarios, and agrees with Westinghouse's judgement that it would be grossly disproportionate to implement any of the considered changes given the low likelihood of the events considered and the risk benefits the changes could bring (Ref. 23).

4.4.4 Enhanced Power Supply for Communication Systems

136. Westinghouse considered the feasibility of enhancing the communication system to provide extended means of off-site and intra-plant communications during an SBO. The proposed enhancement is to extend the capability of powering the communication systems during an SBO. Westinghouse found that the design option would produce significant benefits to human performance at a relatively low cost. Therefore, on this basis, Westinghouse found this resilience enhancement to reduce risks ALARP for GDA. Westinghouse identified the following design change in its DCP:

- APP-GW-GEE-5264 Enhanced Power Supply for the UKP **AP1000** Communication System

137. I have verified that the associated DCP is present and has been approved for inclusion in the GDA design reference point (Ref. 32).

138. One of the key issues emerging from post-Fukushima lessons learnt was that the lack of reliable communication systems contributed to increased operator stress and confusion along with difficulty co-ordinating response. Therefore, ONR enhanced SAP ESR.7 to emphasise the expectation that reliable systems for on- and off-site communications should be available in case they are required. Therefore, I welcome and accept Westinghouse's proposal to enhance the power supply for its communication systems.

4.4.5 SFP Makeup Enhancement to Reduce Operator Actions

139. The design basis of safety case for the SFP was assessed during GDA Step 4 Fault Studies assessment and judged to be broadly acceptable (Ref. 1). As part of GDA

Issue GI-AP1000-FS-01, this safety case has been consolidated in the PCSR (Section 9.7) (Ref. 49) and further strengthened by additional substantiation on the claims on operators to place stranded fuel in a safe place.

140. Westinghouse has provided a clear description of its evaluation of potential enhancements to the SFP makeup. The main objective of the proposed design enhancement was to eliminate the operator action to align the PCCWST with the SFP to provide water makeup within the first 72 hours after a BDB event. However, the proposed design enhancement did not meet that objective – in Westinghouse's view, the objective is not feasible without making substantial changes to the SFS and PCS system designs which are not justified given the very small nuclear safety improvements that would be provided.

141. I am content that Westinghouse has considered whether any further improvements could be made to enhance the makeup capability. Given the negligible safety and human performance impacts and the adequacy of the existing design, I consider Westinghouse's conclusion that the design change is not reasonably practicable to be reasonable, and I agree with this.

142. The fault studies inspector informed Westinghouse via RQ-AP1000-1478 (Ref. 48) that the safety case for fuel stranded above the racks was a concern. Westinghouse responded that this will be considered as part of its response to GI-AP1000-FS-01. Therefore, further consideration of fuel stranded above the racks is not required as part of Westinghouse's post-Fukushima response and the fault studies inspector has accepted this (Ref. 23).

4.4.6 SFP Instrumentation Enhancements

143. Westinghouse has performed an analysis to determine whether it would be feasible to enhance the power source and range of SFP level instrumentation during an SBO.

144. With regard to the power source enhancement, Westinghouse has provided a clear description of its current design. The **AP1000** plant provides SFP water level indication and alarms for level set points in the MCR. These level instruments are Class 1 transmitters powered via the Protection and Safety Monitoring System (PMS). After an SBO due to an extreme BDB external event, the PMS automatically receives power from the Class 1 DC batteries when the loss of AC power occurs. The terminal height of the first row of Class 1 DC batteries is located in the auxiliary building below ground level, and thus could be lost in a severe BDB flood event. The capability to monitor the SFP water level would then be lost.

145. As a result of its analysis to determine whether it would be feasible to enhance the power source of the SFP level instrumentation, Westinghouse proposes to enhance the protection of Class 1 batteries against a BDB flood. If batteries are protected, the SFP level monitoring would be available in case of a BDB flooding event, in line with the expectations of SAP EHF.7. I consider the additional protection of the batteries against flooding to be a positive enhancement to the robustness of the SFP instrumentation. Further details regarding this resilience enhancement are provided above in the 'BDB flood protection for Class 1 batteries' section.

146. With regard to the range of SFP level instrumentation, Westinghouse has clearly described its current design. The SFP level instrumentation for the **AP1000** plant covers the span of the SFP from the pool deck to the top of the spent fuel assemblies. Thus, the instrumentation can measure to the top of the active fuel region.

147. It has become RGP in the UK following Fukushima to consider in severe accident analysis and site emergency arrangements the consequences of a catastrophic drain of a SFP. It is important to note that the **AP1000** plant has no piping or instrument

penetrations below the spent fuel height. However, Westinghouse has nonetheless considered a BDB event causing a failure of the SFP walls or floor that results in the draining of the SFP. In this unlikely scenario, cooling water can be provided via spray headers placed on either side of the SFP.

148. The proposed instrumentation enhancement is to extend the range of the SFP level measurement span to the bottom of the SFP racks. In my view, additional information on SFP water level to the bottom of the SFP racks would provide the operator with greater situational awareness in case of a BDB event. It could inform the emergency response, for example, to indicate whether makeup water is being retained and if it is necessary to switch to a spray function.

149. As a result of its analysis, Westinghouse concluded that it is not reasonably practicable to provide SFP instrumentation enhancements to enable coolant levels to the bottom of the fuel to be measured. This is because Westinghouse did not identify any existing technology able to provide suitable level indication in case frothing occurs below the top of active fuel caused by steam generation in the fuel assembly. In my view, Westinghouse's first submission did not provide a clear explanation of why it considered frothing below the top of active fuel would reduce the reliability of the level monitoring. Through a series of RQs (Refs 48 and 50), the fault studies inspector and I raised questions regarding the practicability of providing SFP level indication below the level of the top of active fuel stored in the SFP. Westinghouse responded by explaining the sequence of operations available to the **AP1000** plant in the event of reduction of water level within the SFP, including use of the spray system.

150. Westinghouse identified other means of establishing situational awareness, such as through the monitoring of sumps (Ref. 50). I accept this as providing an improvement in situational awareness. I have raised an AF to ensure that potential technological developments are considered by the future licensee. This finding requires that the future licensee shall consider the practicability of installing a level indication for the SFP capable of providing water level indication below top of fuel height.

151. Westinghouse has confirmed that space is available for deployment of such a system, in the pool and in the vicinity of the pool, assuming it is a development of existing technologies. In my view, it is appropriate that further consideration of the possibility of enhancing SFP instrumentation be considered at the site-specific stage once the site-specific external hazard curves have been derived and the potential for a BDB event to occur that may require the use of enhanced instrumentation can be considered. I am therefore content to accept Westinghouse's response for GDA subject to the following AF:

CP-AF-AP1000-CC-03-01: The licensee shall consider the practicability of installing a level indication for the spent fuel pool capable of providing water level indication below top of fuel height. Such indication is desirable in order to provide situational awareness of SFP coolant inventory during beyond design basis events.

152. It is intended that the AF delivers a reconsideration of the SFP level indication available during a BDB event. While Westinghouse did not identify a mature technology suitable for deployment within its design, it is conceivable that such a technology could become available between the GDA assessment and deployment of the **AP1000** design in the UK.

153. The questions raised regarding the availability of SFP level indication for situational awareness during a BDB will apply to all similarly stored fuel across the global fleet of PWRs and boiling water reactors (BWRs). It is therefore reasonable to expect the

availability and maturity of such technology to mature before the first deployment of the **AP1000** design in the UK.

4.4.7 Improved Post-72 Hour Cable Connections

154. Westinghouse has clearly described its evaluation of whether enhancing the means of connecting the off-site DGs to the **AP1000** plant would reduce risks ALARP. The off-site DGs are the primary means of delivering a limited number of functions after 72 hours to allow the continued operation and monitoring of the Class 1 SSCs (see Table 8A-5 of the PCSR) (Ref. 51). On-site ancillary equipment is also provided for the same reason but these are not protected against external hazards.

155. Westinghouse evaluated two potential options for providing an enhancement to the means of connecting the off-site DGs. The first option is to install two flanges in the auxiliary building wall and two flanges in the floor just inside the wall. This option would significantly shorten the length of temporary cables required to connect mobile equipment in case of an SBO lasting more than 72 hours. Westinghouse considers that this option reduces risks ALARP as the benefits it provides are reasonable. I agree with this view.

156. The second option is to install additional permanent Class 1 cable inside the plant to further shorten the cables needed to connect mobile equipment for an event of this type. Although the second option does have some additional benefits due to the reduction in the length of temporary cabling required, Westinghouse considers that the laying of temporary cabling can be adequately accounted for in the site-specific emergency plan. Westinghouse's conclusion is that the second option (permanent Class 1 cables) does not reduce risks ALARP. I agree with this view. The second option provides only a minor safety benefit which is grossly disproportionate to the costs. The costs for the second option are significant, mainly due to the Class 1 seismic supports that would be required.

157. In my view, the implementation of the first option provides adequate improvements to nuclear safety in line with lessons learnt post-Fukushima.

158. Westinghouse identified the following design change in its DCP:

- APP-GW-GEE-5261 UKP Specific Improved Post-72 Hour Cable Connections and Addition of Flange Connections for PCCAWST

159. I have verified that the associated DCP is present and has been approved for inclusion in the GDA design reference point (Ref. 32). This DCP incorporates the addition of improved cable connections as part of the proposed design change. On this basis, Westinghouse's consideration and endorsement of improved post-72 hour cable connections is accepted.

4.4.8 Enhanced Off-site Equipment Locations and Connections

160. Westinghouse has provided a clear description of its assessment to determine whether to enhance the provisions for on-site placement of off-site equipment for use during a sustained BDB flood. This would involve designing into the **AP1000** plant the provisions to erect a platform that would provide a location for the off-site equipment. This platform would be located above the sustained BDB flood level postulated by Westinghouse. As part of its assessment, Westinghouse also examined whether existing ancillary equipment could be used instead of relying on off-site mobile equipment.

161. Westinghouse concluded that it would be possible to use the existing ancillary equipment during a sustained BDB flood. The benefits to this approach would depend

on the site-specific risk of a BDB sustained flood. If that risk is significant, then the benefit would be significant. There is also a human performance benefit of Option A. It would remove the need to coordinate with offsite personnel to transport in the offsite equipment. This would reduce the workload of plant staff managing the event response. There are no significant additional costs associated with this approach as the only requirement is further analysis at the site-specific phase (once the site-specific external flooding hazard curve has been derived) to ensure that the equipment would not be adversely affected by a sustained flood. Westinghouse does not consider the option to design in the provisions to erect a platform for off-site equipment to be a reasonably practicable solution at the GDA stage. This is due to the significant costs associated with this approach and the fact that it may not be necessary depending on site context.

162. In my view, consideration of the placement and use of off-site mobile equipment for BDB flooding is primarily a site-specific matter. This will be assessed by a future licensee as part of normal business. Westinghouse's evaluation of the potential options is useful and will provide input to the site-specific analysis to enable a future licensee to understand the **AP1000** plant's potential vulnerabilities to external flooding. I consider Westinghouse's evaluation of enhanced off-site equipment locations and connections to be adequate for GDA, and on this basis it is accepted.

4.4.9 Hardening of Ancillary Equipment

163. Westinghouse has provided a clear description of its analysis examining the efficacy of enhancing the protection of the ancillary diesel generator (ADG) and PCCAWST against external hazards. For any design basis or BDB event, the PCCAWST (like the ADG) provides basic functions to support the Class 1 passive systems after 72 hours post-accident. The PCCAWST contains sufficient volume to provide simultaneous flow for SFP and containment cooling from 72 hours to 7 days post-accident. As part of my assessment, I considered the analysis for potential protection enhancements against external flooding, earthquakes, and external missiles and wind loads.

164. Regarding external flooding, Westinghouse analysis has shown that the ADG and supporting equipment will retain functionality during a postulated BDB sustained flood but would be unlikely to retain functionality during a rapid flood. This is because of the hydrodynamic loads associated with the rapid flood postulated by Westinghouse. To protect the ADG from the hydrodynamic loads associated with the rapid flood, a number of design changes would need to be implemented. Similarly, under sustained flood conditions the PCCAWST would still be operational. However, the rapid flood could cause the tank to move due to the buoyancy forces in concert with the hydrodynamic loading, in which case the tank would no longer be operational. Preventing this eventuality would involve adding a structural piling system and increasing the rebar in the foundation or adding a breaker wall to dissipate the hydrodynamic load. Westinghouse does not propose to implement these design changes due to the insignificant safety benefit and moderate costs involved.

165. The rapid flood postulated by Westinghouse would be due to a tsunami or dam break. In my view, the risk from external flooding in the UK context would be significantly more likely to be dominated by a sustained flood such as river or sea flooding, although a future licensee would be required to assess this at the site-specific phase as part of normal business. I agree with Westinghouse that design changes at the GDA phase are not required due to the likely low risks involved. On this basis, Westinghouse's decision not to harden the ADG or PCCAWST against rapid external flooding is accepted.

166. Regarding earthquakes, for the ADG and PCCAWST to be changed from a SC-II component to a SC-I component, the materials would have to be changed from

Category 2 to Category 1 which would entail further qualification and documentation requirements. Westinghouse does not consider there to be a safety benefit gained from these upgrades, as both SC-I and SC-II structures are designed to the loads of the SSE in accordance with SAPs ECE.6. In my view, this conclusion is acceptable at the GDA phase. As part of normal business, a future licensee will be required to examine potential reasonably practicable resilience enhancements following performance of the site-specific probabilistic seismic hazard analysis (PSHA), derivation of the seismic hazard curve, and examination of seismic fragilities for the site-specific context.

167. Regarding external missiles and wind loads, to increase protection of the ADG, enhancements to the protection of the exhaust louvres and the outside access doors would be required. To protect the PCCAWST, wall thickness would need to be increased and the structure protecting the piping to the auxiliary building would need to be strengthened. Westinghouse states that the **AP1000** reactor is protected against hurricane wind loads of 322 km/h, which exceeds and bounds the most intense UK tornados. In my view, this conclusion is acceptable at the GDA phase. As part of normal business, a future licensee will be required to derive a BDB wind hazard curve and to verify Westinghouse's claim that additional enhancements against BDB wind do not provide a tangible benefit in the UK context.

168. In summary, Westinghouse has provided an adequate exploration of potential vulnerabilities of the ancillary equipment to a range of BDB external hazards. It has also provided a clear analysis of the potential costs and benefits from providing additional hardening of ancillary equipment appropriate to GDA. At the GDA stage, BDB margins against external hazards can only be assessed generically in relation to the UK context, and Westinghouse's assessment is accepted. The future licensee's site-specific review will determine whether further mitigation measures are required to reduce risks to ALARP as part of normal business.

4.4.10 Additional Connections for On-site Water Storage Tanks

169. Westinghouse has provided a clear description of its assessment to determine the feasibility of adding connections to the on-site water storage tanks to improve their accessibility during an extended SBO. Westinghouse examined the largest water tanks to determine whether it would be feasible to improve their accessibility in case of an extended SBO. It determined that the fire protection water storage tanks and the condensate water storage tank are already easily accessible and no design changes are required. This conclusion appears reasonable and is accepted.

170. Westinghouse reviewed the methodology for obtaining water from the PCCAWST, which is the largest water storage tank available on site. The original intention was that a portable pump would be connected to a hose that is dropped into the PCCAWST through the top of the tank. Westinghouse determined that it would be possible to enhance the PCCAWST design by adding a new connection line and a new isolation valve and flanged connection. In my view, this would provide a more readily accessible connection point and would also enhance conventional safety during an event as the operator would no longer be required to climb the stairs on the exterior of the tank.

171. Westinghouse identified the following DCP:

- APP-GW-GEE-5261 UKP Specific Improved Post-72 Hour Cable Connections and Addition of Flange Connections for PCCAWST

172. I have verified that the associated DCP is present and has been approved for inclusion in the GDA design reference point (Ref. 32). This DCP incorporates the additional flange connections for the PCCAWST as part of the proposed design change. On this

basis, Westinghouse's consideration of the additional connections for on-site water storage tanks is accepted.

4.4.11 Hardening of Class 2 Systems

173. Westinghouse has provided a clear description of its assessment to determine whether enhancing the protection of the **AP1000** plant's Active Class 2 systems for an SBO caused by BDB external hazards is reasonably practicable.

174. In addition to its Class 1 passive systems, the **AP1000** plant also has active Class 2 systems to provide further redundancy and diversity. These are powered by off-site AC power or on-site standby DGs and are designed to minimise the challenges to the passive safety systems. These systems are not protected against the full range of external hazards. Westinghouse performed an analysis to determine whether it would be reasonably practicable to enhance the protection of the Class 2 SSCs, including protection of their ability to provide AC and DC power, cooling water, heating, ventilation and air conditioning (HVAC) and C&I. Westinghouse's conclusion was that it would be grossly disproportionate as the cost impact would be very high and the safety benefits insignificant. I agree with this conclusion. Even if the resilience of the Class 2 SSCs is enhanced, they would still have less margin and lower reliability than the Class 1 passive systems. However, the fault studies inspector and I queried whether it would be reasonably practicable to enhance the resilience of a selection of Class 2 systems (Ref. 48). I queried whether it is desirable for accident recovery (even if the reactor is being safely cooled by passive systems) to restore the RNS and component cooling water system (CCS). I asked Westinghouse to consider whether there are advantages in protecting the RNS and CCS (even partially) so that the time to restore them is quicker.

175. Westinghouse responded by analysing the partial protection of the RNS and CCS against external flooding. Its analysis concluded that there was very little, if any, gain in margin enhancement from protection of these systems, and this is accepted.

176. It is important to note that the **AP1000** plant relies on passive safety systems to provide long-term accident mitigation with limited operator action and no reliance on off-site or on-site AC power. Westinghouse states that the primary Class 1 passive systems provided with the **AP1000** plant ensure a coping time of at least 72 hours as part of the design basis. In addition, the **AP1000** plant has Class 1 back-up features that can independently maintain safety functions during an SBO. In my view, given the prominence of the passive Class 1 SSCs in achieving the deterministic and probabilistic objectives of the **AP1000** safety case, I agree with Westinghouse's conclusion that upgrading the Class 2 SSCs is not required.

4.4.12 Conclusion to the Assessment of Westinghouse's Review of Potential Resilience Enhancements

177. I consider that Westinghouse's analysis of potential resilience enhancements that could be applied to the **AP1000** design is adequate. The process Westinghouse used to determine whether a margin enhancement reduces risks as appropriate for GDA is clearly described within its submission. Westinghouse's process includes a consideration of RGP applicable to the enhancement. It describes the optioneering process undertaken for each enhancement.

178. Westinghouse has focused on the risks under its control and has emphasised nuclear safety considerations when reaching its conclusions for each enhancement. I consider Westinghouse's review process and conclusions to be aligned with RGP as described in ONR TAG 5 "Guidance on the Demonstration of ALARP" (Ref. 6), and within ONR's SAPs (Ref. 5) and they are accepted.

4.5 Relevant PCSR Updates

179. Chapter 12 of the **AP1000** PCSR provides a description of how external hazards were addressed for the generic **AP1000** design. As part of my assessment, I have considered the revisions to Chapter 12 of the PCSR as they relate to GI-AP1000-CC-03. I have also considered whether the changes to the SAPs post-Fukushima undermine any aspects of Chapter 12 of the PCSR.

180. Westinghouse has now added a post-Fukushima assessment subsection to Chapter 12 as Appendix 12B (Ref. 15). This is consistent with Westinghouse's PCSR Chapter 12 strategy letter WEC-REG-0211R (Ref. 52) and the GI-AP1000-CC-03 resolution plan.

181. The new post-Fukushima subsection of Chapter 12 of the PCSR clearly describes the events at Fukushima and the Westinghouse approach to reviewing relevant lessons learnt. The chapter references UKP-GW-GGR-201 and summarises its contents. It concludes that, for a Fukushima-like event, the **AP1000** design demonstrates robustness with respect to BDB external hazards.

182. Overall, I am satisfied that the claims, arguments and evidence laid down within Chapter 12 of the PCSR accurately reflect the submissions provided by Westinghouse for GDA Issue GI-AP1000-CC-03. In my view, the PCSR, taken together with the submissions provided to resolve this GDA issue, form an adequate update to the safety case taking into account post-Fukushima lessons learnt. In addition, the contents of Chapter 12 of the PCSR remain valid when considered against the post-Fukushima SAPs updates. Other revisions to Chapter 12 that do not relate to GI-AP1000-CC-03 have been assessed as part of GDA Issue GI-AP1000-CC-02 and are summarised in the relevant assessment note (Ref. 53).

4.6 Assessment Finding

183. During my assessment I identified one item for a future licensee to take forward in its site-specific safety submissions.

184. **CP-AF-AP1000-CC03-01: The licensee shall consider the practicability of installing a level indication for the Spent Fuel Pool (SFP) capable of providing water level indication below top of fuel height. Such indication is desirable in order to provide situational awareness of SFP coolant inventory during beyond design basis events.**

185. This matter does not undermine the generic safety submission. In addition to the resolution of this AF, the future licensee will perform its own assessment of post-Fukushima lessons learnt as part of normal business.

186. The resolution of GDA Issue GI-AP1000-CC-03 has not altered the AFs resulting from the Step 4 assessment.

5 ENVIRONMENT AGENCY'S ASSESSMENT OF GDA ISSUE GI-AP1000-CC-03

The text in this section of the report has been provided by the Environment Agency.

187. This GDA issue was identified to ensure that the lessons learnt from the Fukushima accident were considered within GDA for the **AP1000** design. GDA Issue GI-AP1000-CC-03 required Westinghouse to demonstrate how it will take account of the lessons learnt from the events at Fukushima. This included those arising from Westinghouse's own internal reviews and lessons, and recommendations identified in HM Chief Inspector's interim and final reports (Refs 2 and 3).

188. The EA[‡] has considered whether changes to the design or the generic site to ensure resilience of the **AP1000** design would have an impact on the Environment Report (ER) (Ref. 54) and associated references (which together represent the "environment case" for GDA).

5.1 Scope of Assessment Undertaken

189. The EA assessed changes to both the design and the generic site to ensure resilience of the **AP1000** design.

5.2 Assessment

190. The EA's assessment focused on the deliverables received from Westinghouse in response to this GDA issue. I considered whether any resulting design changes had any impact on the environment case and in particular the ER.

5.3 Assessment Findings

191. Westinghouse has provided sufficient design reviews and supporting analyses to demonstrate the robustness of the generic **AP1000** design at normal operating and shutdown states against severe seismic and flooding events. Westinghouse provided appropriate evidence to demonstrate the ability of the generic **AP1000** plant to retain its radioactive inventory following events which result in loss of electrical power and/or cooling. Westinghouse has provided sufficient responses to the Chief Inspector's recommendations from the Fukushima lessons learnt reports. I am satisfied that the ER submission has been updated appropriately to reflect relevant changes.

192. Westinghouse's assessment identified design changes in response to GI-AP1000-CC-03 and each has been assessed through Westinghouse's design change process and incorporated in the relevant documentation supporting GDA.

193. None of these GI-AP1000-CC-03-related design changes impacted significantly on the environment case. Westinghouse ultimately concluded that the resolution of this GDA issue had no significant impacts to the existing environment assessment bases, including additional generation of radioactive or other wastes, spent fuel management, changes to plant design or site layout, changes to decommissioning planning, or changes to anticipated operational actions as the result of planned responses to the GDA issue. This seems a reasonable conclusion based on the EA's assessment.

[‡] *Since April 2013, Natural Resources Wales (NRW) has been the environmental regulator for nuclear sites in Wales. As new nuclear power stations may be built in Wales, NRW has participated in the latter stages of this GDA work and the EA and NRW have jointly reached the conclusions set out in this section of the document.*

6 ASSSESSMENT CONCLUSIONS

194. This report presents the findings of GDA Issue GI-AP1000-CC-03 relating to the **AP1000** closure phase.

195. The requirements of the GDA issue were wide ranging, for which Westinghouse has needed to review, document and apply a significant volume of post-Fukushima lessons learnt across a large number of technical disciplines.

196. I have undertaken a detailed assessment of Westinghouse's key submission, UKP-GW-GGR-201 (Ref. 29), and supplementary submission, UKP-GW-GL-109 (Ref. 30), for this GDA issue. I have also looked at how Westinghouse has incorporated the five design changes emerging from the application of post-Fukushima lessons learnt into the **AP1000** safety case and design documentation. I have verified that the new DCPs implementing the five design changes identified for GI-AP1000-CC-03 are included in the design reference point (DRP). In addition, I have reviewed the updated sections of the PCSR for evidence that the results of the work for this GDA issue is reflected in the top-level safety case documentation.

197. As a result of my assessment, I conclude that:

- Westinghouse's response to GDA Issue GI-AP1000-CC-03 provides a thorough and comprehensive review of post-Fukushima lessons learnt and demonstrates the **AP1000** plant's robustness against a wide range of external hazard challenges.
- Westinghouse has adequately addressed the recommendations set out in the HM Chief Inspector's interim and final reports and the UK national STFs.
- Westinghouse has considered a wide range of international lessons learnt from the Fukushima event as part of its review.
- Potential safety enhancements to the **AP1000** design were suitably identified, considered and screened against ALARP considerations as appropriate for GDA.
- The **AP1000** design safety has been enhanced as a result of the lessons learnt from the Fukushima event.
- One AF has been raised in response to GI-AP1000-CC-03.

198. My judgement is based upon the following factors:

- Westinghouse has delivered clear reports in line with the resolution plan.
- Interactions between Westinghouse and ONR throughout the resolution of the issue have ensured that the final report is in accordance with regulatory expectations.
- Westinghouse has identified practicable safety enhancements and has incorporated them into the **AP1000** design.

199. I have also considered the judgements made as part of my assessment of this GDA issue against the common position set out by MDEP, as described in Section 2.4 of this report. I found them to be fully consistent.

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

201. **CP-AF-AP1000-CC03-01: The licensee shall consider the practicability of installing a level indication for the Spent Fuel Pool (SFP) capable of providing water level indication below top of fuel height. Such indication is desirable in**

order to provide situational awareness of SFP coolant inventory during beyond design basis events.

202. In summary, I am satisfied that GDA Issue GI-AP1000-CC-03 can be closed.

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Table 1:

Relevant Safety Assessment Principles considered during the assessment

The SAPs listed in part 1 of this table contain significant changes relevant to GDA resulting from the ONR response to the Fukushima event. These changes occur in either the SAPs themselves or the associated explanatory paragraphs. A comprehensive list of the changes to SAPs in the 2014 version and relevance to the Fukushima event is available on the ONR website (Ref. 55). The SAPs listed in part 2 of this table are also referenced in my assessment, but have not changed significantly following Fukushima.

SAP No	SAP Title	Description
Part 1 – SAPs significantly modified to take into account post-Fukushima lessons learnt		
EKP.3	Defence-in-depth	Nuclear facilities should be designed and operated so that defence-in-depth against potentially significant faults or failures is achieved by the provision of multiple independent barriers to fault progression.
EHA.18	Beyond design basis events	Fault sequences initiated by internal and external hazards beyond the design basis should be analysed applying an appropriate combination of engineering, deterministic and probabilistic assessments.
EHA.7	'Cliff-edge' effects	A small change in design basis fault or event assumptions should not lead to a disproportionate increase in radiological consequences.
EHA.11	Weather conditions	Facilities should be shown to withstand weather conditions that meet design basis event criteria. Weather conditions beyond the design basis that have the potential to lead to a severe accident should also be analysed.
EHA.12	Flooding	Facilities should be shown to withstand flooding conditions up to and including the design basis event. Severe accidents involving flooding should also be analysed.
ECE.1	Functional performance	The required safety functions and structural performance of the civil engineering structures under normal operating, fault and accident conditions should be specified.
ECE.6	Loadings	Load development and a schedule of load combinations, together with their frequencies, should be used as the basis for structural design. Loadings during normal operating, testing, design basis fault and accident conditions should be included.
ELO.4	Minimisation of the effects of incidents	The design and layout of the site, its facilities (including enclosed plant), support facilities and services should be such that the effects of faults and accidents are minimised.
EQU.1	Qualification procedures	Qualification procedures should be applied to

		confirm that structures, systems and components will perform their allocated safety function(s) in all normal operational, fault and accident conditions identified in the safety case and for the duration of their operational lives.
EHT.3	Heat sinks	A suitable and sufficient heat sink should be provided.
ESR.7	Communications systems	Adequate communications systems should be provided to enable information and instructions to be transmitted between locations on and, where necessary, off the site. The systems should provide robust means of communication during normal operations, fault conditions and severe accidents.
EES.9	Simultaneous loss of service	Essential services should be designed so that the simultaneous loss of both normal and back-up services will not lead to unacceptable consequences.
EHF.7	User interfaces	Suitable and sufficient user interfaces should be provided at appropriate locations to provide effective monitoring and control of the facility in normal operations, faults and accident conditions.
EPS.5	Discharge routes	Pressure discharge routes should be provided with suitable means to ensure that any release of radioactivity or toxic material from the facility to the environment is minimised. The potential to create an explosive atmosphere from the discharge should also be considered.
FA.7	Consequences	Analysis of design basis fault sequences should use appropriate tools and techniques, and be performed on a conservative basis to demonstrate that consequences are ALARP.
Part 2 – Other SAPs referenced in this assessment report		
SC.7	Safety case maintenance	A safety case should be actively maintained throughout each of the lifecycle stages, and reviewed regularly.
EHA.4	Frequency of initiating event	For natural external hazards, characterised by frequency of exceedance hazard curves and internal hazards, the design basis event for an internal or external hazard should be derived to have a predicted frequency of exceedance that accords with Fault Analysis Principle FA.5. The thresholds set in Principle FA.5 for design basis events are 1 in 10 000 years for external hazards and 1 in 100 000 years for man-made external hazards and all internal hazards (see also paragraph 629).
EHA.6	Analysis	The effects of internal and external hazards that could affect the safety of the facility should be analysed. The analysis should take into account

		hazard combinations, simultaneous effects, common cause failures, defence-in-depth and consequential effects.

Table 2:
UK lessons learnt from the Fukushima event – stress test findings, interim recommendations and final recommendations

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
STF-1	Licensees should provide ONR with the decision-making process to be applied to their considerations along with a report which describes the sentencing of all their considerations. The report will need to demonstrate to ONR that the conclusions reached are appropriate.	This requirement is the responsibility of the licensee. However, during GDA Westinghouse is providing ONR with a report (UK **AP1000** Plant Post-Fukushima Assessment, UKP-GW-GGR-201) that includes information that addresses this finding for the general **AP1000** design. The report details the robust response of the **AP1000** plant design to BDB events. It also lists potential areas for improvement (margin enhancements) and provides ALARP assessments of those areas.	Accepted One of the reasons for the creation of GI-AP1000-CC-03 as part of the GDA Step 4 assessment was to address this STF and similar recommendations. Westinghouse's submissions have adequately described its consideration of post-Fukushima lessons learnt and its associated potential resilience enhancements.
STF-2	The nuclear industry should establish a research programme to review the Seismic Hazard Working Party (SHWP) methodology against the latest approaches. This should include a gap analysis comparing the SHWP methodology with more recent approaches such as those developed by the Senior Seismic Hazard Analysis Committee (SSHAC).	This is an industry-wide effort. Seismic hazard derivation methods that underpin the design basis seismic hazards for the EDF NGL sites are also employed by Magnox and Sellafield Ltd. EDF NGL commissioned a gap analysis, carried out by independent seismic hazard experts, comparing the SHWP and current methodologies including a procedural view of SSHAC. Gap analysis including stakeholder engagement is complete.	Accepted The methodologies for seismic site characterisation are the responsibility of site licensees and as such fall outside GDA scope. There is nothing in the **AP1000** design information that would limit the methodologies which could be deployed for seismic site characterisation. Westinghouse's approach is to select a generic seismic design spectrum, with the expectation that a site-specific spectrum produced to modern standards would be bounded by the design spectrum. Other GDA RPs have adopted this approach, which has proved adequate. There is no reason to think that the design spectrum would not bound a site-specific derivation of seismic spectrum to modern standards.
STF-3	Licensees should undertake a further review of the totality of the required actions from operators when they are claimed in mitigation within external hazards safety cases. This should also extend into BDB events as appropriate.	The site licensee has the responsibility to establish the site emergency plan and training of the site personnel and contractors. However, the **AP1000** plant is very robust. The plant can achieve and maintain safe shutdown with extreme events for 72 hours without the need for operator action. After 72 hours only limited operator actions are required to support continued operation of the Class 1 passive features. In most cases, installed equipment will be available to support these safety functions out to 7 days. After 7 days, the plant continues to function in the same manner except that additional consumables (water, fuel, oil) supplies are required. Water supplies include water in various plant storage tanks, raw water (eg lake, river, ocean) and off-site supplies. If the installed post-72 hour equipment is unavailable, then a few small pieces of off-site equipment can be brought to the site to support continued passive system operation.	Accepted The ONR human factors inspector has reviewed the Westinghouse response to STF-3 against the EHF suite of SAPs. The **AP1000** design intent is to minimise the active systems and operator actions required to deliver safety functions. The inspector raised a RQ (Ref. 39), which partially related to the assessment of this STF. The RQ sought to clarify the assumptions being made regarding operator actions, while acknowledging the responsibility of site licensees to provide details of emergency arrangements. Westinghouse responded with greater detail, including the operation of design enhancements identified through the CC-03 response process. The ONR inspector agreed that the response was acceptable (Ref. 26) and Westinghouse incorporated it into the final report.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
STF-4	Licensees should undertake a further systematic review of the potential for seismically induced fire which may disrupt the availability of safety-significant SSCs in the seismic safety case and access to plant areas.	**AP1000** design features addressing this finding are identified.	Accepted Class 1 passive systems are fail-safe and do not require any electrical power or C&I to operate them. These systems are designed with redundant divisions located in separate fire areas. The deterministic case for internal fire has been assessed as part of GDA issue IH-01 (Ref. 40). Detailed fire loading assessment will only be available during detailed design associated with site licensing and construction. Step 4 of GDA considered consequential hazards. Analysis of the detailed design by a future licensee will be assessed against SAP EHA.6.
STF-5	Licensees should further review the margins for all safety-significant SSCs, including cooling ponds, in a structured systematic and comprehensive manner to understand the BDB sequence of failure and any cliff-edges that apply for all external hazards.	The **AP1000** reactor has been evaluated for BDB hazards and margin to cliff-edges: • Comprehensive seismic margin assessment performed. Seismic margin analysis extends to at least 67% above the SSE design basis PGA of 0.3 g. • Conservative flooding margin assessment performed. Assessments have shown that the safety functions (eg core cooling, containment integrity and SFP cooling) are maintained even for extreme BDB events. The use of a conservative standard design further increases these margins for most sites.	Accepted The external hazards assessor has assessed consideration of BDB events as part of the response to GI-AP1000-CC-03. The civil engineering assessor challenged the design of the SFP and deemed it to be adequate in accordance with SAP ECE.1 following the resolution of a RQ (Ref. 34) as recorded in assessment response sheet (Ref. 27). Assessment of both seismic and flooding response, as described in Section 4 of this report, indicate the absence of cliff-edge effects in accordance with SAP EHA.7 and FA.7. A site licensee will be responsible for the determination of hazard return frequencies through site characterisation activities.
STF-6	Licensees should review further the margin to failure of the containment boundary and the point at which containment pressure boundary integrity is lost should be clearly established for the advanced gas-cooled reactors (AGR) and Magnox stations.	Applies to AGR and Magnox NPPs. Although the **AP1000** reactor is not an AGR or a Magnox NPP, its containment design has been evaluated for its margin to failure for use in PSA severe accident sequences.	Accepted STF-6 relates to AGR and Magnox stations. Margin to failure is considered in the seismic analysis of the **AP1000** reactor, which has been assessed in Section 4 of this report.
STF-7	Licensees should undertake a more structured and systematic study of the potential for floodwater entry to buildings containing safety-significant SSCs from extreme rainfall and/or overtopping of sea defences.	A conservative flooding margin assessment was performed. It was shown that the safety functions, such as core cooling, containment integrity and SFP cooling are maintained even for extreme BDB events. UKP-GW-GGR-201 details the robust response of the **AP1000** plant design to BDB events. In addition, ALARP evaluations have been conducted on potential margin enhancements which increase margins regarding floodwater entry to buildings containing safety-significant SSCs for sites that have such a risk. • BDB flooding protection for the Class 1 battery and equipment rooms • BDB flooding protection for the post-72 hour ancillary equipment • BDB flooding protection for the Class 2 defence-in depth systems	Accepted The extreme external flooding scenarios, considered by Westinghouse and discussed in Section 4.1 of this report, provide confidence that the plant is designed to withstand BDB flooding with an appropriate margin.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
STF-8	Licensees should further investigate the provision of suitable event-qualified connection points to facilitate the reconnection of supplies to essential equipment for BDB events.	Westinghouse's submission describes connection of off-site / transportable equipment to support long-term operation of the Class 1 passive systems for an indefinite time. The use of such off-site / transportable equipment provides an alternative to the installed ancillary equipment that extends the BDB capabilities of long-term support. Secure Class 1 connection points are provided in the **AP1000** plant design.	Accepted The electrical engineering inspector has considered and accepted the Westinghouse response to STF-8 (Ref. 24). One of the resilience enhancements proposed for the UK **AP1000** plant concerns the provision of fixed connection points for portable generators to back up the ancillary generators. This will enhance the capability to establish a power supply in the event of a total loss of electrical power.
STF-9	Licensees should further investigate the enhancement of stocks of essential supplies (cooling water, fuel, carbon dioxide, etc.) and extending the autonomy time of support systems (eg battery systems) that either provide essential safety functions or support emergency arrangements.	The Class 1 passive systems are designed to provide for at least 72 hours of SBO coping capability. This coping capability includes large batteries that provide for 72 hours of MCR lighting and post-accident instrumentation displays. To extend the operation of the Class 1 systems for an indefinite time beyond 72 hours only requires a few small pieces of equipment. Post-72 hour support is provided via installed ancillary equipment as well as via equipment from off site. Recommendations on portable equipment are provided. Westinghouse will work with a future licensee to help in developing the site emergency plan and emergency support facilities.	Accepted The philosophy for the **AP1000** design is for the design to be self-sufficient for 72 hours and for the post-72 hour support to be simple and planned. The FLEX approach is in direct response to the lessons learnt from the Fukushima event. The licensee is responsible for emergency arrangements and as such it is outside the scope of GDA. Assessment of the information provided by electrical and emergency arrangements inspectors indicates that a licensee can provide adequate stocks to satisfy STF-9 (Refs 24 and 28).
STF-10	Licensees should identify safety-significant prime mover-driven generators and pumps that use shared support systems (including batteries, fuel, water and oil) and should consider modifying those prime movers systems to ensure they are capable of being self-sufficient.	The **AP1000** plant design passive approach to safety eliminates the need for AC power, cooling water systems and pumps to provide core, spent fuel and containment cooling. The **AP1000** plant Class 1 passive safety systems required for SBO are self-actuating (do not require any electrical power or C&I) for actuation or continued operation. After 72 hours, limited support is required to support continued operation of the PCS and SFP cooling. The power required for makeup water to these two functions is low.	Accepted The **AP1000** design passive approach to safety and FLEX equipment are designed to address the concerns which led to the raising of STF-10. The electrical and emergency arrangements inspectors' assessment of the Westinghouse response indicates that Westinghouse has planned for suitable equipment and connections to be available to satisfy STF-10 (Refs 24 and 28).

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
STF-11	Licensees should further consider resilience improvements to equipment associated with the connection of the transmission system to the essential electrical systems (EES) for severe events.	The **AP1000** plant design passive approach to safety eliminates the need for AC power, cooling water systems and pumps to provide core, spent fuel and containment cooling.	Accepted The **AP1000** design philosophy in response to loss of off-site power (LOOP) has been accepted through the GDA Step 4 assessment. The electrical engineering inspector's assessment confirms that STF-11 is addressed adequately (Ref. 24).
STF-12	Magnox Ltd should assess the progressive loss of electrical systems on all aspects of the fuel route and address any implications.	Not applicable to the **AP1000** plant design. Finding applies to Magnox NPP.	Accepted This STF is not relevant to the **AP1000** design in the scope of GI-AP1000-CC-03.
STF-13	Magnox Ltd should demonstrate that all reasonably practical means have been taken to ensure integrity of the fuel within the dry fuel stores in the extremely unlikely event of the natural draft air ducting becoming blocked.	Not applicable to the **AP1000** plant design. Finding applies to Magnox NPP.	Accepted This STF is not relevant to the **AP1000** design in the scope of GI-AP1000-CC-03.
STF-14	Licensees should confirm the extent to which resilience enhancements are to be made to existing equipment and systems that are currently installed at nuclear power plants. Information should be provided on the equipment and systems that may be affected and the nature of the resilience enhancements, including interconnectivity with mobile back-up equipment.	During GDA Westinghouse is providing ONR with an evaluation of the **AP1000** plant response to BDB events and enhancements to increase margins. The report details the robust response of the **AP1000** plant design to BDB events. It also lists potential areas for improvement (margin enhancements) and provides ALARP assessments of those areas.	Accepted As part of Westinghouse's internal lessons learnt review conducted it identified safety enhancements and considered them for implementation via an ALARP assessment. Section 4.1 of this report presents an assessment of this process and its outcomes.
STF-15	Licensees should complete the various reviews that they have highlighted so that ONR can assess their proposals and associated timescales. These reviews should look in detail at on-site emergency facilities and arrangements, off-site facilities, facilities for remote indication of plant status, communication systems, contents and location of BDB containers and the adequacy of any arrangements necessary to get people and equipment on and around the site under severe accident conditions. Any changes to arrangements and equipment will require appropriate training and exercising.	Part applies to utility plans and procedures. Other parts overlap with STF-3, 8 and 9.	Accepted This report provides the output of an equivalent review to those identified in STF-15.
STF-16	Licensees should review the symptom-based emergency response guidelines (SBERG) and severe accident guidelines (SAG) taking into account improvements to the understanding of severe accident progression, phenomena and the equipment available to mitigate severe accidents. This review should also take into account the fuel route. Once completed, appropriate training and exercising should be arranged.	The **AP1000** plant has been designed to mitigate core melt sequences using installed features (ie to support in-vessel retention). The EOPs address use of these features.	Accepted The EOPs provide an equivalent function to SBERGs and SAGs. The licensee will be responsible for demonstration of adequacy and the provision of training.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
STF-17	Licensees should further review the systems required to support long-term claims on the pre-stressed concrete pressure vessel containment capability in severe accident conditions.	**AP1000** containment a steel pressure vessel, not pre-stressed concrete. Note that in an extended SBO, the probability of a core melt accident in the **AP1000** plant is very low. Various diverse means exist to ensure the integrity of the **AP1000** steel containment vessel is maintained following core melt sequences.	Accepted The design, materials and support systems for the **AP1000** design pressure vessel are significantly different from those for a pre-stressed concrete pressure vessel. The specific concerns leading to the raising of STF-17 are not applicable to the **AP1000** design pressure vessel.
STF-18	EDF Energy Nuclear Generation Ltd should complete its feasibility study into the installation of FCV, installation of passive autocatalytic hydrogen recombiners and flexible means of injecting water into the Sizewell B containment.	Consideration of FCV and enhanced hydrogen control measures are evaluated for the **AP1000** plant design.	Accepted The Westinghouse internal lessons learnt review considered the installation of FCV. Section 4.1 of this report (Ref. 23) discusses the ONR assessment. Adequately dealt with.
STF-19	Reports on the progress made in addressing the conclusions of the licensees considerations and the ONR findings should be made available to ONR on the same timescale as that for HM Chief Inspector's recommendations (June 2012). These should include the status of plans and details of improvements that have been implemented.	Applies to existing operating plants.	Accepted This STF is not relevant to **AP1000** design in the scope of GI-AP1000-CC-03.
IR-1	The Government should approach IAEA, in co-operation with others, to ensure that improved arrangements are in place for the dissemination of timely authoritative information relevant to a nuclear event anywhere in the world.	Not applicable to Westinghouse or the **AP1000** plant design; this is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
IR-2	The Government should consider carrying out a review of the Japanese response to the emergency to identify any lessons for UK public contingency planning for widespread emergencies, taking account of any social, cultural and organisational differences.	Not applicable to Westinghouse or the **AP1000** plant design; this is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
IR-3	The Nuclear Emergency Planning Liaison Group should instigate a review of the UK's national nuclear emergency arrangements in light of the experience of dealing with the prolonged Japanese event.	Not applicable to Westinghouse or the **AP1000** plant design; this is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
IR-4	Both the UK nuclear industry and ONR should consider ways of enhancing the drive to ensure more open, transparent and trusted communications, and relationships, with the public and other stakeholders.	The response to this recommendation is not directly related to the results of the detailed post-Fukushima assessment of the **AP1000** plant design documented in the report. This recommendation relates to organisational aspects of the nuclear industry in the UK. As the plant designer, Westinghouse encourages open dialogue with the regulator and public in an open venue that allows and provides for mandatory public comment and review periods of the new plant licensing process. Westinghouse will work with the regulator to facilitate these types of exchanges, if desired. The framework for this structure is delineated in a report entitled "The Way Forward: U.S. Industry Leadership in Response to the Accidents at the Fukushima Dai-ichi Nuclear Power Plant".	Accepted The GDA process and its associated communication strategy and expectation on RPs are intended to deliver openness and transparency in the process. This Westinghouse response and ONR assessment are undertaken within this context. Westinghouse has complied with the expectations for openness and transparency within the GDA process.
IR-5	Once further detailed information is available and studies are completed, ONR should undertake a formal review of the SAPs to determine whether any additional guidance is necessary in light of the Fukushima accident, particularly for "cliff-edge" effects.	Not applicable to Westinghouse or the **AP1000** plant design; this is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
IR-6	ONR should consider to what extent long-term severe accidents can and should be covered by the programme of emergency exercises overseen by the regulator.	Not applicable to Westinghouse or the **AP1000** plant design; this is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
IR-7	ONR should review the arrangements for regulatory response to potential severe accidents in the UK to see whether more should be done to prepare for such very remote events.	Not applicable to Westinghouse or the **AP1000** plant design; this is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
IR-8	The UK nuclear industry should review the dependency of nuclear safety on off-site infrastructure in extreme conditions, and consider whether enhancements are necessary to sites' self-sufficiency given the reliability of the grid under such extreme circumstances.	With the **AP1000** plant passive safety approach, the risk associated with LOOP events is significantly reduced in comparison to advanced active light water reactors. The **AP1000** design's reliance on external (and internal) infrastructure to achieve its safety functions has been minimised: • The **AP1000** plant Class 1 passive safety features do not rely on AC power or cooling water systems to provide core and SFC following extreme external hazard events. The passive features that mitigate these events self-actuate. • The **AP1000** plant can achieve and maintain safe shutdown for more than three days with very minimal operator actions during the most limiting BDB extreme external events without AC power or cooling water systems. • After three days, simple operator actions are needed to extend the operation of the passive features to seven days using installed or off-site equipment.	Accepted In accordance with other recommendations and STFs, the **AP1000** design aims to minimise reliance on grid connections and off-site infrastructure. GDA Step 4 assessment has accepted this approach. A future licensee will be responsible for evaluating the reliability of infrastructure and its impact on safety.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
IR-9	Once further relevant information becomes available, the nuclear industry should review what lessons can be learnt from the comparison of the events at the Fukushima-1 (Fukushima Dai-ichi) and Fukushima-2 (Fukushima Dai-ni) sites.	Discussion and assessment of this recommendation has been performed. Appendix L of the report specifically compares the events at Fukushima-1 and Fukushima-2 and explains the applicability of the differences to the design of the **AP1000** plant design. The **AP1000** plant design fundamentally changes this situation with its use of Class 1 passive safety features that do not rely on AC power or cooling water systems. This design approach provides a plant design that is much more robust for extreme external hazards and provides much longer grace periods. The **AP1000** SBO mitigation measures do not rely on AC power and water heat sink. In addition, the SBO features self-actuate without the need for DC power or C&I systems.	Accepted The Westinghouse response and the consideration of the final recommendations and STFs, and ONR 2014 SAP updates which post-date IR-9, are considered to account for the lessons learnt from the comparison between Fukushima Dai-ichi and Fukushima Dai-ni.
IR-10	The UK nuclear industry should initiate a review of flooding studies, including from tsunamis, in light of the Japanese experience, to confirm the design basis and margins for flooding at UK nuclear sites, and whether there is a need to improve further site-specific flood risk assessments as part of the periodic safety review programme, and for any new reactors. This should include sea-level protection.	The use of passive A1 systems that self-actuate and do not rely upon AC power or cooling water systems greatly reduces the vulnerability of the **AP1000** plant design to BDB flooding events. During site licensing, the licensee will further address this recommendation as part of its site-specific flood risk assessment.	Accepted A future licensee will address the consideration of susceptibility to flooding. An external hazards inspector has considered and deemed adequate the protection of the **AP1000** design against flooding. Section 4.1 of this report presents details of this inspection.
IR-11	The UK nuclear industry should ensure that safety cases for new sites for multiple reactors adequately demonstrate the capability for dealing with multiple serious concurrent events induced by extreme off-site hazards.	For the purpose of GDA, the **AP1000** plant is designed as a single-unit site. That said, the presence of several units on the site has limited impact on the plants' response to extreme off-site hazards as no equipment important to nuclear safety will be shared between units on a multi-unit site. During site licensing, the licensee will further address this recommendation for aspects such as the effect of a multi-unit site on operational response programmes such as emergency planning.	Accepted The scope of the **AP1000** design GDA is limited to a single unit. A fault studies inspector has considered the response to IR-11 and raised no comments. A future licensee will be responsible for addressing IR-11 if operating multi-unit site. This requirement is now captured in the ONR SAPs (Ref. 23). No comments following editorial correction in issue 1 (Ref. 48).
IR-12	The UK nuclear industry should ensure the adequacy of any new spent fuel strategies compared with the expectations in the SAPs of passive safety and good engineering practice.	The **AP1000** design features multiple, diverse lines of defence to maintain spent fuel cooling without the need for AC power or cooling water systems. A long-term strategy of spent fuel storage is part of RP-01. It is also captured as part of the decommissioning programme during site-specific licensing.	Accepted Details of spent fuel strategy will form part of the site license application and will be judged against the revised 2014 SAPs. The robustness of the SFP has been considered on a cross-discipline basis, including a RQ (Ref. 50) being raised and resolved (Ref. 23). Section 4 of this report discusses this in greater detail.
IR-13	The UK nuclear industry should review the plant and site layouts of existing plants and any proposed new designs to ensure that safety systems and their essential supplies and controls have adequate robustness against severe flooding and other extreme external events.	The design basis flood remains under the 100 m (100 ft) elevation (plant grade) for all **AP1000** plant sites and adequate siting in regard to this requirement provides the first line of defence for flooding protection. In addition, the report evaluates the margin against extreme BDB extreme external events. As part of the evaluation, a detailed ALARP assessment was performed to improve the margin against BDB events.	Accepted The robustness to severe flooding and other external events is considered in response to the Westinghouse internal lessons learnt review in section 4 of this report and is deemed adequate. A future licensee will be responsible for characterising the site hazard.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
IR-14	The UK nuclear industry should ensure that the design of new SFPs close to reactors minimises the need for bottom penetrations and lines that are prone to siphoning faults. Any that are necessary should be as robust to faults as are the ponds themselves.	Piping connections to connected pools are limited in their potential to drain the SFP because they interface with the SFP through the transfer gates whose lowest elevation is above the top of the fuel. Additionally, the normal SFP cooling lines that provide suction and return flow of cooling water to the pool are equipped with siphon breakers to prevent draining of the pool below the top of the fuel in the event of a line break.	Accepted Considered in the fault studies assessment (Ref. 23). Strictly as Westinghouse defines the SFP, there are no penetrations low down. However, the adjacent (and joined) pits do penetrate. This has been adequately covered in Step 4, the PCSR and GI-AP1000-FS-01 (Ref. 1).
IR-15	Once detailed information becomes available on the performance of concrete, other structures and equipment, the UK nuclear industry should consider any implications for improved understanding of the relevant design and analyses.	The specific lessons learnt relative to the performance of concrete or other structures and equipment cannot be fully assessed until more specific information is made available for review by the industry. The SSCs required to bring the plant to a safe, stable condition are assessed to withstand the seismic conditions. The goal of the **AP1000** plant seismic margin assessment is to demonstrate that fragility limits for this equipment will not be exceeded during a seismic event with a PGA of 0.5 g.	Accepted The requirement to ensure the safety of nuclear licensed facilities includes lessons learnt is contained in SAP MS.4, which a future licensee will be subject to. The Westinghouse response to IR-15 summarises the current information available. Response to lessons learnt for a future licensee will not be limited to those from the Fukushima event.
IR-16	When considering the recommendations in this report the UK nuclear industry should consider them in light of all extreme hazards, particularly for plant layout and design of Class 1 plant.	The **AP1000** is less vulnerable to external hazards because: 1. **AP1000** design is "fails safe". Even with a loss of all electrical power, instrumentation and control (I&C) controls, and instrument air, the **AP1000** plant design passively aligns crucial Class 1 systems to a safe state, which protects the reactor core and the SFP. 2. **AP1000** design is self-reliant. The **AP1000** plant passive safety systems reduce the importance of ac electrical power or heat sinks such as the service water cooling interface with nearby bodies of water. The **AP1000** plant ultimately uses ambient air as a heat sink. 3. **AP1000** design is self-contained. All structures, systems, or components required to maintain the **AP1000** plant in a safe shutdown are located within the steel containment vessel and surrounded by the robust steel-concrete-steel shield building. The shield building and the containment protect the safe shutdown systems and equipment from external events.	Accepted The information provided through Westinghouse's internal lessons learnt review, discussed in section 4 of this report, and the GDA Step 4 assessment provide analysis of the **AP1000** design response to extreme hazards. In terms of extreme weather conditions, I assessed Westinghouse's response against SAP EHA.11, which states that facilities should be shown to withstand weather conditions that meet the design basis event criteria and BDB weather conditions should be analysed. I judged the response to be adequate within the scope of GDA.
IR-17	The UK nuclear industry should undertake further work with the National Grid to establish the robustness and potential unavailability of off-site electrical supplies under severe hazard conditions.	For the **AP1000** plant design, a LOOP event leading to a loss of all AC power on site or SBO is a design basis event. The **AP1000** PSA shows that the risk to the public from LOOP / SBO is greatly reduced for the **AP1000** plant. In addition, the licensee will be required to provide off-site equipment that can be brought to the site within the 72-hour coping time. Because of the use of Class 1 passive safety features, only a few, small pieces of off-site equipment are required. As a result, the robustness of the off-site electrical grid is not a significant risk to the **AP1000** plant.	Accepted IR-17 is intended to be addressed by site licensees. It is noted that the **AP1000** design does not place a reliability claim on the grid for safety functions.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
IR-18	The UK nuclear industry should review any need for the provision of additional, diverse means of providing robust sufficiently long-term independent electrical supplies on site, reflecting the loss of availability of off-site electrical supplies under severe conditions.	The **AP1000** plant design's use of A1 passive systems that do not rely on AC power, cooling water systems or pumps greatly reduces the importance of off-site and on-site electrical power. For the **AP1000** plant design, the underlying strategies for coping with extended loss of AC power events involve a three-stage approach: 1. Initial coping is through installed plant equipment, without any AC power sources or makeup to the UHS. The **AP1000** passive design features provide core, containment and spent fuel cooling for 72 hours, without reliance on AC power sources. 2. Following the 72-hour passive system coping time, support is required to continue passive system cooling. This support can be provided by installed plant ancillary equipment or by off-site equipment interfacing with installed plant connections. The installed ancillary equipment and stored cooling water can support passive system cooling from three days after the accident up to seven days after the loss of off-site power. If this installed support equipment is not available, then a few, small pieces of off-site equipment would be brought to the site. 3. To extend the passive system cooling time to beyond seven days (to an indefinite time), a limited amount of off-site assistance and resources are required.	Accepted The electrical engineering inspector has assessed and accepted as adequate the approach to post-72 hour system support (Ref. 24), and I agree with his conclusion. The future licensee will be responsible for the detailed selection of equipment and its deployment. Westinghouse's main additional commitment concerns the provision of fixed connection points for portable generators to back up the ancillary generators, as described in Section 4 of this report. This will enhance the capability to establish a power supply in the event of a total loss of electrical power. In addition, Westinghouse has stated a requirement for a future licensee to locate a suitable generator local to the site. This addresses a concern the electrical engineering inspector raised previously regarding the practicality of sourcing and connecting a suitable generator following an extreme event. The descriptions on the loads to be supplied by the portable generator and its required rating are not clear and it will be important for detailed engineering that these requirements are clarified. However, the electrical engineering inspector believes that the safety claims in the electrical topic area should cover the determination of these points, with claims that define the approach to defining loads and sizing the generators based on these loads.
IR-19	The UK nuclear industry should review the need for, and if required, the ability to provide longer-term coolant supplies to nuclear sites in the UK in the event of severe off-site disruption, considering whether further on-site supplies or greater off-site capability is needed. This relates to both carbon dioxide and fresh water supplies, and for existing and proposed new plants.	The **AP1000** plant PXS does not require external makeup water to support core cooling. The inventory stored in the RCS and the PXS are sufficient to maintain long-term cooling of the core once actuated for up to 14 days. After 14 days, if normal active Class 2 systems are not recovered, it may be necessary to transition to open loop RCS cooling using installed Class 1 passive systems. Class 1 DC power and C&I systems would be required for this transition. Makeup water to spent fuel cooling and passive containment cooling is not required for 72 hours after an SBO. After this time, assuming off-site AC power or standby off-site AC power has not been restored, additional sources of makeup water will be required to continue the operation of containment and spent fuel cooling. There are a number of sources on site that can be readily used for this purpose.	Accepted The Westinghouse lessons learnt section of the report addresses the long-term support for the **AP1000** design. Section 4.1 of this report details its assessment.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
IR-20	The nuclear industry should review site contingency plans for pond water makeup under severe accident conditions to see whether they can and should be enhanced given the experience at Fukushima.	The **AP1000** plant design features multiple, diverse lines of defence to ensure SFP cooling can be maintained for design basis events and BDB accidents. Even for BDB accidents with postulated pool damage and multiple failures in the passive Class 1 systems and in the defence-in-depth active systems, the **AP1000** plant SFP spray system provides an additional line of defence to prevent spent fuel damage. The **AP1000** plant design has also made provisions for extreme BDB events, such as a failure of the SFP walls or floor that result in the draining of the SFP. In this unlikely scenario, cooling water can be provided by the two redundant spray headers located on either side of the SFP.	Accepted The resilience of SFP cooling to severe accident conditions is considered in light of the Westinghouse lessons learnt review. A RQ (Ref. 50) was raised and resolved and one Assessment Finding was raised (Ref. 23), as addressed by Section 4 of this report.
IR-21	The UK nuclear industry should review the ventilation and venting routes for nuclear facilities where significant concentrations of combustible gases may be flowing or accumulating to determine whether more should be done to protect them.	The **AP1000** plant design includes passive and active combustible gas control to prevent the accumulation of hydrogen from reaching explosive limits within the containment. The passive hydrogen control is comprised of two PARs located in the upper compartment of containment. Severe accident hydrogen control is provided by 66 hydrogen igniters that are powered by off-site AC power, standby DGs or DC power. The igniters are distributed throughout the containment compartments.	Accepted The fault studies inspector considered the response to IR-21 and raised comments through a RQ (Ref. 48) requesting additional clarity. Westinghouse resolved these comments to the satisfaction of the inspector. Hydrogen management has been considered in the design and in response to Fukushima lessons learnt (Ref. 23).
IR-22	The UK nuclear industry should review the provision of on-site emergency control, instrumentation and communications in light of the circumstances of the Fukushima accident including long timescales, widespread on- and off-site disruption, and the environment on site associated with a severe accident.	Emergency planning and off-site communication are outside the scope of GDA. The site licensee will be responsible for establishing the site emergency plan.	Accepted The C&I inspector considered the Westinghouse response to IR-22. The inspector raised comments were raised in a RQ (Ref. 35), which were adequately addressed in the Westinghouse response. The recommendation requires the review of the provision of on-site emergency control, instrumentation and communications in light of the circumstances of the Fukushima accident. Although emergency planning is out of scope for GDA, Westinghouse provided information regarding the options available for control, instrumentation and communication provision in the **AP1000** design to deal with an on-site emergency in accordance with SAP EHF.7. The C&I inspector judged this information adequate for the purposes of GDA (Ref. 22).

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
IR-23	The UK nuclear industry, in conjunction with other organisations as necessary, should review the robustness of necessary off-site communications for severe accidents involving widespread disruption.	As a plant designer, this recommendation is not directly applicable to Westinghouse. A site licensee should address this recommendation.	Accepted A future licensee will be responsible for emergency arrangements and the details of off-site communications. Although the full answer to this recommendation should involve the licensee and hence is out of scope for the GDA, the RP provided information regarding the options available in the **AP1000** design to enable off-site communication of key information and monitoring parameters. The C&I inspector judged this information adequate for the purposes of GDA (Ref. 22).
IR-24	The UK nuclear industry should review existing severe accident contingency arrangements and training, giving particular consideration to the physical, organisational, behavioural, emotional and cultural aspects for workers having to take actions on site, especially over long periods. This should take account of the impact of using contractors for some aspects on site such as maintenance and their possible response.	With the support of Westinghouse, a future licensee will develop severe accident contingency arrangements and training for the plant operating staff. The **AP1000** plant is designed with severe accident mitigations features such as in-vessel retention to limit the consequences of a severe accident.	Accepted A future licensee is responsible for the delivery of activities identified within IR-24.
IR-25	The UK nuclear industry should review, and if necessary extend, analysis of accident sequences for long-term severe accidents. This should identify appropriate repair and recovery strategies to the point at which a stable state is achieved, identifying any enhanced requirements for central stocks of equipment and logistical support.	The site licensee will develop site emergency arrangements and facilities. Westinghouse will work with future licensees to identify additional strategies to include in contingency planning to provide long-term support to the site in the event of a severe accident.	Accepted The fault studies inspector considered the Westinghouse response to IR-25 and raised no comments (Ref. 23). No comments.
FR-1	All nuclear site licensees should give appropriate and consistent priority to completing Periodic Safety Reviews (PSRs) to the required standards and timescales, and to implementing identified reasonably practicable plant improvements.	This recommendation is not directly applicable to Westinghouse, as the plant designer. A site licensee should address this recommendation.	Accepted A future licensee will be responsible for addressing the issues raised in FR-1. The requirement for a PSR lies in Licence Condition 15. SAP SC.7 includes consideration of the expectations for a PSR.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
FR-2	The UK nuclear industry should ensure that SSCs needed for managing and controlling actions in response to an accident, including plant control rooms, on-site emergency control centres and off-site emergency centres, are adequately protected against hazards that could affect several simultaneously.	In general, the **AP1000** plant requires far fewer operator actions because of the use of Class 1 passive systems. In addition, the Class 1 passive features that mitigate external hazard events self-actuate. The **AP1000** MCR is the primary control location and as such has the most robust hazard protection including a Class 1 passive habitability control system. The **AP1000** plant design also provides an area in the annex building that can be used as a Technical Support Contractor (TSC) if a licensee chooses. This location is designed as a SC-II structure to protect against the effects of an earthquake or other potential external hazards. The off-site emergency control centres are out of scope of the standard design since they are site-specific.	Accepted A future licensee has primary responsibility for the elements of FR-2. Site-specific hazard characterisation will be required to demonstrate adequate discharge of the expectations.
FR-3	SSCs needed for managing and controlling actions in response to an accident, including plant control rooms, on-site emergency control centres and off-site emergency centres, should be capable of operating adequately in the conditions, and for the duration, for which they could be needed, including possible severe accident conditions.	The **AP1000** plant MCR is designed to be able to operate following an accident that causes a loss of all station AC power. A Class 1 passive habitability control system is provided for this room. Key equipment in the MCR is powered by Class 1 batteries for 72 hours following the loss of all AC power. The required equipment in the MCR is also qualified to operate under the conditions expected in the MCR following an accident.	Accepted The C&I inspector (Ref. 22) primarily assessed the Westinghouse response to FR-3. Westinghouse's response to the recommendations refers to the robustness of the MCR and its enhanced habitability compared to control rooms in current operating reactors. Following a request for additional clarification, Westinghouse provided further details on the potential role of the RSR in this scenario.
FR-4	The nuclear industry should ensure that adequate Level 2 PSAs are provided for all nuclear facilities that could have accidents with significant off-site consequences and use the results to inform further consideration of severe accident management measures. The PSAs should consider a full range of external events including BDB events and extended mission times.	The standard plant PSA includes a Level 2 PSA analysis. It considers a wide range of external events and examines plant response to both design basis and BDB events. Site-specific information is required to provide a detailed Level 2 PSA; this will be generated for each **AP1000** plant site.	Accepted The PSA inspector assessed the Westinghouse response to FR-4 and judged it to be adequate for GDA (Ref. 25), and I agree with his view. He noted that Westinghouse provided a Level 2 PSA at GDA Step 4. This included a consideration of the risk from certain external hazards (seismic events and flooding). ONR has agreed with Westinghouse that the PSA will be developed further during the licensing phase to include comprehensive coverage of external hazards. The current PSA includes BDB events and extended mission times. The current Level 2 PSA has been used to support the post-Fukushima ALARP assessment for severe accident management measures in Westinghouse's primary report to address GDA issue GI-AP1000-CC-03 (Ref. 29). The PSA submissions also address the lessons learnt from Fukushima and their implementation in the PSA model. They will continue to develop as the future licensee develops a site-specific PSA model. In my view, this is sufficient to close out this recommendation for GDA.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
FR-5	The relevant Government departments in England, Wales and Scotland should examine the adequacy of the existing system of planning controls for commercial and residential developments off the nuclear licensed site.	Not applicable. This requirement is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
FR-6	The nuclear industry with others should review available techniques for estimating radioactive source terms and undertake research to test the practicability of providing real-time information on the basic characteristics of radioactive releases to the environment to the responsible off-site authorities, taking account of the range of conditions that may exist on and off site.	The response to this recommendation is not directly related to the results of the detailed post-Fukushima assessment. This recommendation relates to organisational aspects of the nuclear industry in the UK. Westinghouse will work with future licensees to identify source terms / releases and the resulting dose calculations (on site and off site) that are specific to accident sequences as well as site / weather specific.	Accepted The response to FR-6 is not within the scope of GDA as it is a requirement on the wider industry.
FR-7	The Government should review the adequacy of arrangements for environmental dose measurements and for predicting dispersion and public doses and environmental impacts, and to ensure that adequate up-to-date information is available to support decisions on emergency countermeasures.	Not applicable. This requirement is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
FR-8	The Government should consider ensuring that the legislation for the new statutory body requires ONR to be open and transparent about its decision making, so that it may clearly demonstrate to stakeholders its effective independence from bodies or organisations concerned with the promotion or utilisation of nuclear energy.	Not applicable. This requirement is a Government action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
FR-9	The UK Government, nuclear industry and ONR should support international efforts to improve the process of review and implementation of IAEA and other relevant nuclear safety standards and initiatives in light of the Fukushima-1 (Fukushima Dai-ichi) accident.	The response to this recommendation is not directly related to the results of the detailed post-Fukushima assessment documented in the report. This recommendation relates to organisational aspects of the nuclear industry in the UK.	Accepted The response to FR-9 is not within the scope of GDA as it is a requirement on the wider industry.
FR-10	ONR should expand its oversight of nuclear safety-related research to provide a strategic oversight of its availability in the UK as well as the availability of national expertise, in particular that needed to take forward lessons from Fukushima. Part of this will be to ensure that ONR has access to sufficient relevant expertise to fulfil its duties in relation to a major incident anywhere in the world.	Not applicable. This requirement is an ONR action.	Accepted This recommendation is not applicable to the **AP1000** design in GI-AP1000-CC-03.
FR-11	The UK nuclear industry should continue to promote sustained high levels of safety culture among all its employees, making use of the National Skills Academy for Nuclear and other schemes that promote “nuclear professionalism”.	The response to this recommendation is not directly related to the results of the detailed post-Fukushima assessment documented in this report. This recommendation relates to organisational aspects of the nuclear industry in the UK. Westinghouse recognises the importance of strengthening nuclear safety culture, and that the key to an industry-leading nuclear safety culture is the collective behaviours of the leaders and individuals in emphasising safety over other competing goals.	Accepted The response to FR-11 is not within the scope of GDA as it is a requirement on the wider industry.

Finding Type	Finding	Westinghouse response – summarised (Ref. 29)	ONR assessment
FR-12	Reports on the progress that has been made in responding to the recommendations in this report should be made available to ONR by June 2012. These should include the status of the plans, and details of improvements that have been implemented by that time.	The details in this report describe the Westinghouse progress and actions that have been taken to respond to the recommendations in the ONR Final Report.	Accepted GI-AP1000-CC-03 identified ONR's expectations for the Westinghouse response to the lessons learnt from the Fukushima event, and the conclusion of this report is that Westinghouse's response is adequate.

Table 3:
Design changes arising from GI-AP1000-CC-03 agreed for inclusion in GDA

Design Change Description	Design Change Proposal Title	DCP Reference (Ref. 32)
Beyond design basis flood protection for Class 1 batteries	Changes to United Kingdom **AP1000** Plant (UKP) to increase the Protection of Class 1 Batteries from Beyond Design Basis Flood	APP-GW-GEE-5252
Enhanced power supply for communication system	Enhanced Power Supply for the UKP **AP1000** Communication System	APP-GW-GEE-5264
Improved post-72 hour cable connections	UKP Specific Improved Post-72 Hour Cable Connections and Addition of Flange Connections for PCCAWST	APP-GW-GEE-5261
Enhanced off-site equipment (DGs, pumps) location / connections during sustained flood	UKP Specific Improved Post-72 Hour Cable Connections and Addition of Flange Connections for PCCAWST	APP-GW-GEE-5261
Additional connections for on-site water storage tanks	UKP Specific Improved Post-72 Hour Cable Connections and Addition of Flange Connections for PCCAWST	APP-GW-GEE-5261