REGULATORY OBSERVATION

REGULATOR TO COMPLETE

RO unique no.:	RO-ABWR-0041
Date sent:	11th March 2015
Acknowledgement required by:	01st April 2015
Agreement of Resolution Plan required by:	08th April 2015
Resolution of Regulatory Observation required by:	*To be determined by the Hitachi-GE Resolution Plan*
TRIM Ref.:	2015/30525
Related RQ / RO No. and TRIM Ref. (if any)**:**	
Observation title:	UK ABWR Probabilistic Safety Analysis: Identification of Applicable External Hazards
Technical area(s) PSA External Hazards	**Related technical area(s)** Fault Studies Human Factors Internal Hazards

Regulatory Observation

Summary

ONR's assessment during Step 3 of GDA of the Requesting Party (RP) submission "Identification of External and Internal Hazards" (Ref. 1) has identified shortfalls. The objective of this Regulatory Observation (RO) is to state ONR's expectations related to the Identification of External and Internal Hazards for the UK Advanced Boiling Water Reactors (ABWR) Probabilistic Safety Analyses (PSA) and request the RP to respond to the shortfalls identified by ONR's review.

Background and Regulatory Expectations

ONR's assessment during Step 3 of GDA of the RP submission "Identification of External and Internal Hazards" (Ref. 1) has identified a number of shortfalls where regulatory expectations are not met.

ONR raised RQ-ABWR-0335 to request the review of the screening approach adopted for the UK ABWR PSA against international good practice. The RP response to this RQ did not provide sufficient justification to demonstrate that the approach adopted in the PSA screening meets relevant good practice. ONR recognises that the RP has undertaken analyses to support the design development. However, this work was aimed to support design basis analyses (DBA) and will need to be developed further to meet the PSA requirements.

As part of ONR assessment of Ref. 1, a number of guidance documents were reviewed to provide a consensus regarding the approach and technical basis for the identification and prioritisation of external hazards to be considered in the GDA PSA (Ref. 2, 3, 4, 5, 6, 7, 8, 9).

The concerns highlighted by the ONR's assessment are summarized below.

<u>Identification of External Hazards</u>

ONR review has identified that the initial list of external hazards identified for the UK ABWR PSA does not appear to be fully comprehensive when compared with international literature (eg. Ref. 3 to 6). For example, a number of hazards are not explicitly considered in the external events list for use in the screening process in Ref.1. Specific examples were discussed with the RP during the PSA technical workshop in February 2015 (Ref. 10). The RP topic report on external hazards protection (Ref.11) identifies some of these hazards as part of existing groups in Ref.1. However, it is not clear whether the definition of these groups is adequate for PSA.

<u>Combinations of Hazards</u>

In addition to the list of external and internal hazards the possibility of risk significant combinations of such hazards has been the subject of international guidance documents. EPRI 1022997, Identification of External Hazards for Analysis in Probabilistic Risk Assessment (Ref.3), defines the following categories of multiple simultaneous or sequential hazards:

- Coincidental Hazards: Multiple randomly occurring hazards affecting the plant simultaneously (e.g., earthquake and tornado).
- Correlated Hazards: Multiple hazards affecting the plant simultaneously due to similar causal factors (e.g., snow and low air temperatures).
- Consequential Hazards: One or more hazards that affect the plant as a result of an initial hazard (e.g., seismic event and seismic-induced internal flooding).

Similar definitions are provided in Ref.11 and chapter 6 of the UK ABWR PCSR (Ref.12). However, combinations of hazards do not appear to have been considered as part of the identification of hazards for the PSA.

IAEA Guidance SSG-3 (Ref. 9) provides the following guidance for identification of hazard combinations:

> *'6.11. A list of potential combined hazards should be developed. Combinations of hazards may have a significantly higher impact on plant safety than each individual hazard considered separately, and the frequency of occurrence of a combination of hazards may be comparable to that of the individual hazards, e.g. high level water due to storm precipitation and dam failure caused by storm precipitation. The process of identification of hazards should include the identification of all combinations of hazards that may be significant for risk.*
>
> *6.12. The possible combinations of hazards should be identified on the basis of the list of individual internal and external hazards. The entire list of potential hazards should be used for this purpose before any screening analysis is carried out. Usually, combined hazards involve only natural hazards (e.g. a combination of heavy wind and high sea water level). However, combinations of natural hazards and human-induced hazards are also possible and cannot be excluded a priori (e.g. an increased risk of ship accidents during severe weather conditions).*
>
> *6.13. The general approach used for the identification of a realistic set of combinations of hazards should be based on a systematic check of the dependencies between all internal and external hazards. The following causes for combinations of hazards should be considered:*
>
> *a) Hazards have the potential to occur under the same conditions and at the same time (e.g. high winds and snow precipitation).*
>
> *b) One external hazard can induce other hazards (e.g. a seismically induced external flood accompanied by dam failure)*
>
> *c) External hazards can induce internal hazards (e.g. seismically induced internal fires or floods)*
>
> *d) One internal hazard can induce other internal hazards (e.g. internal floods induced by internal missiles).*
>
> *The impact of combinations of hazards on safety functions should be reassessed as they may affect different safety functions or the same function in a more severe manner than a single hazard ...*
>
> *6.24. Initiating events occurring at the plant may be the result of the impact of a single hazard or a combination of two or more hazards. While using the screening criteria, it should be justified that hazards whose combined impact can result in significant consequences are not excluded from further consideration, even though each of them, considered independently, would make a negligible contribution to risk.*
>
> *6.25. A review of the actual status of the plant and the surroundings should be performed while applying screening criteria, in order to verify that changes in the original design conditions are not significant or are taken into account in the PSA. In particular, changes that have the potential to cause new hazards or to lead to an increased frequency of hazards of a certain magnitude should be thoroughly investigated. '*

These coincident or consequential external events can produce synergistic effects that together may compromise barriers or mitigation systems. It is ONR's expectation that a systematic assessment of those credible external event combinations is desired as part of the hazard identification and prioritization for the UK ABWR PSA.

Prioritisation of External Hazards

The approach and criteria for the UK ABWR screening of hazards presented in the RP's documentation (Ref.1) do not appear to be adequate. In particular, the reasons for excluding hazards from the analysis as not applicable to the UK ABWR are not clear and not fully justified.

There is no set of adequate screening criteria presented in Ref.1. The screening process is dependent on the RP's external hazards (EH) team of experts to use information of the external hazard and design information of the plant to determine the applicability of the hazard. ONR considers that the approach adopted by the RP (eg. reliance on the EH team to perform the hazard screening process) is not a robust approach due to the subjective nature given no fixed screening criteria.

The RP submission indicates that the initiating event frequency used in the screening process is the same value as the limit for "broadly acceptable" risk in paragraph 579 of the SAP: "Screening by occurrence frequency using a limit of once in ten million years (1E-7/yr) in accordance with the SAP". It is not clear how these criteria is used in the screening process and more importantly, these criteria and justification do not meet regulatory expectations:

- SAP paragraph 579 does not reference a screening criteria of 1E-7/yr as cited in the subject report to allow screening of hazards. The subject paragraph of the SAP references frequencies of event sequences that may result in public fatalities – not frequencies of hazards.
- Given the core damage frequency (CDF) for internal events at power claimed by Hitachi-GE, the corresponding screening threshold would need to be much lower than this limit to demonstrate that the risk associated with hazards would be insignificant. It is ONR expectation that hazards are not screened out but prioritised (see below).

Examples of external hazards that have been screened out from the UK ABWR PSA with a justification that does not meet ONR expectations were discussed with the RP during the PSA technical workshop in February 2015 (Ref. 10).

As indicated previously, ONR expectation is that the RP develops a prioritization of external hazards adequately justified for the UK ABWR PSA in line with the expectations of ONR's PSA Technical Assessment Guide (TAG) Ref.2 and international good practice. The following factors should be considered as part of the internal hazards prioritization:

- Magnitude of the hazard vs. the design basis.
- Impact on plant, systems and containment.

Cliff Edge Effects

ONR considers that the treatment of "cliff edge" effects is considered important in ensuring a robust plant design.

One example of this is the treatment of external flood. Screening of external floods for the UK ABWR PSA lacks sufficient information to ensure that low frequency hazards (i.e., hazards with consequential site effects well above the design basis assumptions) are properly incorporated in the risk profile. Specific examples were discussed with the RP during the PSA technical workshop in February 2015 (Ref. 10).

A second example may be the use of a seismic margins assessment (SMA). For SMA analysis, there may be a set of systems, structures, or components (SSCs) that are considered so robust, (e.g., high confidence low probability of failure HCLPF above some threshold) that they are screened from analysis and there is no modelling of that SSC frequency of failure or its attendant margin to failure.

It is ONR's expectation that the RP systematically identify the hazards that are treated within the design basis and compare their frequencies and site effects with beyond design basis hazards and their associated frequencies and consequential site effects to determine if the risk remains low even when lower frequency (higher consequence) events are considered.

Scope of the external hazards analyses

The scope of the external hazards analysis needs to address the following:

- How such hazards are to be treated for plant conditions other than at-power conditions with the containment inerted. These might include:
  - Low power conditions (start-up) with the containment deinerted.
  - Refuel/outage conditions with the containment open and heavy load movements occurring

with multiple equipment unavailable due to maintenance.

For example, it is not clear in the documentation the justification for considering the at-power conditional core damage probability (CCDP) sufficient to screen hazards for these non-at-power conditions from further consideration based on low perceived frequency.

- Other on-site radionuclide sources apart from the reactor. Certain hazards may be legitimately considered as low priority from consideration of resulting core damage for at-power conditions. However, these hazards may, in fact, result in releases from other on-site radionuclide sources (e.g., Spent Fuel Pool SFP, etc.) and therefore should be incorporated into the overall PSA program search for hazards. ONR expectation is that this should be considered in the RP's documentation.

PSA Hazards Screening Supporting Information and Design Considerations

ONR review has also identified issues regarding the lack of clarity regarding references to key hazards information that should support the hazards analyses for the PSA, such as site envelop for external hazards, justification of the criteria used to establish the design attributes, the applicable hazard curves, etc. (see RQ-ABWR-0350).

ONR expectations reflected in the PSA TAG (Section A1-2.7.1) are that:

- The frequencies and magnitude of all hazards selected for analysis are identified.
- The hazard impact analysis (as a function of the magnitude of the hazard if appropriate) is auditable and covers possible initiating events, damage to equipment and structures, and impact on human performance.
- The hazard impact analysis has been undertaken using an adequate method and is auditable.

The hazard curve expressing the frequency versus consequences is not presented for any of the external hazards. The resulting impact of the hazard has not yet been presented by the RP. ONR expectation is that the RP provides this information. The outcomes of the prioritization of hazards could be used to plan the development of the hazards curves.

ONR's PSA TAG also indicates that a hazard impact analysis should be performed as a function of the magnitude of the hazard in an auditable manner. For example, the impact would be measured as damage to SSCs, human interface degradation and containment. ONR expectation is that this information is provided. The potential risk of core damage and releases to the environment resulting from the hazards analyses should be added to the overall risk associated with the UK ABWR.

References:

1. Hitachi-GE Standard ABWR Initiating Events and Estimations for Internal/External Hazards, GA91-9901-0048-00001, Rev. D.
2. ONR, PSA Technical Assessment Guide (TAG), T/AST/030, Rev. 5.
3. Electric Power Research Institute, "Identification of External Hazards for Analysis for Probabilistic Risk Assessment," EPRI 1022997, December 2011.
4. Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities, Revision 2, U.S. Nuclear Regulatory Commission, March 2009.
5. US NRC, PRA Procedures Guide, NUREG/CR-2300, January 1983.
6. IAEA Safety Standards Series, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants," IAEA NS-G-1.5, November 2003.
7. Michael Knochenhauer and Pekka Louko, SKI Report 02:27, "Guidance for External Events Analysis," February 2003.
8. M.K. Ravindra and H. Banon, "Methods for External Event Screening Quantification: Risk Methods Integration and Evaluation Program (RMIEP) Methods Development," NUREG/CR-4839, July 1992.
9. IAEA Safety Standards Series, "Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants", IAEA Guidance SSG-3, 2010.
10. ONR-GDA-CR-14-309 UK ABWR GDA Step 3 Technical Workshop 9th to 12th February 2015. TRIM

2015/62468.

11. GA91-9201-0001-00031. Topic Report on External Hazards Protection. 30 September 2014. TRIM 2014/367758.
12. ABWR GDA – Generic PCSR Chapter 6: External Hazards. http://www.hitachi-hgne-uk-abwr.co.uk/downloads/2014-08-28/UKABWR-GA91-9101-0101-06000-P-RevA.PDF

Regulatory Observation Actions

RO-ABWR-00NN.A1: Identification of External Hazards for the PSA

Hitachi-GE is requested to provide a complete list of possible external hazards consistent with international good practice. This list should include credible external (and internal) event combinations.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-00NN.A2: Prioritisation of External Hazards for the PSA

Hitachi-GE is requested to develop a prioritisation of external hazards in terms of:

- Magnitude of the hazard vs. the design basis.
- Impact on plant, systems and containment.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-00NN.A3 : Combinations of Hazards

1. Hitachi-GE is requested to expand the prioritization of hazards analysis to address plausible combinations of hazards for the PSA.
2. Hitachi-GE is requested to provide the technical basis for assessment of combinations of hazards and the criteria used to prioritize hazard combinations for the PSA.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-00NN.A4: Cliff Edge Effects

Hitachi-GE is requested to systematically identify the hazards that are treated within the design basis and compare their frequencies and site effects with beyond design basis hazards and their associated frequencies and consequential site effects to determine if the risk remains low even when lower frequency (higher consequence) events are considered.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-00NN.A5: Scope of the hazards analyses

1. Hitachi-GE is requested to expand the scope of the external hazards analysis to address how such hazards are to be treated for plant conditions other than at-power conditions with the containment inerted. These might include:
    - Low power conditions (start-up) with the containment deinerted.
    - Refuel/outage conditions with the containment open and heavy load movements occurring with multiple equipment unavailable due to maintenance.
2. Hitachi-GE is requested to provide an analysis of the impact of hazards on other on-site radionuclide sources (e.g., SFP) that could result in releases.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-00NN.A6: Frequency of Hazards and Magnitudes

Hitachi-GE is requested to provide the external hazards curve expressing the frequency versus consequences for the external hazards for risk significant hazards to support the PSA and the hazards prioritization.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-00NN.A7: Hazard Impacts

Hitachi-GE is requested to provide an auditable extenal hazard impact analysis. The impact would be measured as damage to systems, structures, and components (SSCs), human interface degradation and containment.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-00NN.A8: Hazard PSA programme

1. Hitachi-GE is requested to review the hazards PSA programme to include all the hazards for which a more detailed probabilistic evaluation needs to be undertaken in Step 4 in line with the results of the hazards prioritisation develop in Action 2.
2. Hitachi-GE is requested to provide an updated PSA programme to address the hazards impact on other radioactivity sources and plant conditions.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

REQUESTING PARTY TO COMPLETE

Actual Acknowledgement date:	
RP stated Resolution Plan agreement date:	