REGULATORY OBSERVATION

REGULATOR TO COMPLETE

RO unique no.:	RO-ABWR-0079
Date sent:	09/01/2017
Acknowledgement required by:	31/01/2017
Agreement of Resolution Plan Required by:	07/02/2017
Resolution of Regulatory Observation required by:	To be determined by Hitachi-GE Resolution Plan
TRIM Ref.:	2017/9555
Related RQ / RO No. and TRIM Ref. (if any)**:**	RQ-ABWR-0769 (2016/63463)
Observation title:	Turbine Disintegration Safety Case
Technical area(s) Internal Hazards	**Related technical area(s)** Fault Studies PSA Civil Engineering Mechanical Engineering

Regulatory Observation

Summary

Hitachi-GE's proposed safety case on turbine disintegration is based on combined deterministic and probabilistic aspects. Hitachi-GE's proposed Design Basis (DB) safety case is based on a single missile hitting the Heat Exchanger Building (Hx/B). The site location of the HxB has not been optimised against turbine disintegration and a robust deterministic safety case has yet to be developed. ONR has particular concerns with the proposed methodology, claims and arguments, ALARP and the lack of optioneering studies.

The aim of this RO is to ensure that a robust deterministic safety case is developed by:

- Clearly define and substantiate the number of missiles generated by a turbine disintegration event, and impact with buildings, during DB and BDB events.
- Develop a robust deterministic safety case.
- Provide an ALARP justification.

Background

During Step 3 of GDA Hitachi-GE presented its approach to the UK-ABWR Turbine Disintegration Safety Case in the Topic Report on Internal Missiles [1].

ONR assessed this report and RQ-ABWR-0769 was raised. The RQ summarised concerns on the proposed methodology, claims and arguments, ALARP, and lack of optioneering studies.

During Step 4 of the GDA, the safety case for turbine disintegration has been discussed in a number of Internal Hazards (IH) L4 meetings, where Hitachi-GE's presented its progress (SE-GD-0455, SE-GD-0494, and SE-GD-0515).

Hitachi-GE's proposed methodology, safety case development and ONR's concerns are given below:

- Hitachi-GE considers the low trajectory turbine missile strikes to concentrate within an area of 25 degree angle to the turbine wheel planes passing through the end wheels of the low-pressure stage. The 25 degree angle is stated within IAEA Safety Guide NS-G-1.11 [2] which states "*the layout of the main turbine generator should be such that potential critical targets (such as the control room) lie within the area least susceptible to direct strikes from the turbine; that is, within a cone with its axis*

along the axis of the turbine shaft. This arrangement takes account of the fact that large sections of rotors, if ejected, will tend to be expelled within 25° of the plane of rotation. The arrangement does not eliminate the possibility of their hitting a critical target, but it significantly reduces the probability of a direct strike." The current location of the HxB is not optimised against turbine disintegration; it is located within the 25 degrees direct strike. NRC guidance [3] also states that "*Favourably oriented turbine generators are located such that the containment and all or almost all, safety related SSCs outside containment are excluded from the low-trajectory hazards zone".*

- Historically in the UK, 25 and 35 degrees of angle of direct strike have been used for layout optimisation of critical targets, coupled with a robust deterministic safety case. More recently, in the UK, proposed safety cases include much wider angle of direct strike as well as a robust deterministic safety case. This is in recognition of the uncertainty and the amount of evidence available relating to turbine disintegration 25 degree angle of missile ejection, and to also address the need for sensitivity studies.
- Hitachi-GE proposed safety case is based on the assumption that four equal-sized quadrants fragments are formed following disintegration. It has also assumed that two of the missiles are ejected downwards into the turbine plinth and other two are ejected on trajectories which can leave the turbine building. Evidence to substantiate the assumed number of low trajectory missiles and distribution of fragments has not been provided.
- Hitachi-GE acknowledged that turbine disintegration is a DB event and indicated that normal over-speed failure was assumed to occur at a frequency of $1.7x10^{-5}$ per year based on manufacturer information.
- Hitachi-GE proposed that the DB event would be based on one high-energy missile hitting the Hx/B. Evidence to support this assertion has not been provided.
- Hitachi-GE proposed that the target probability of a single missile with the HxB is of the order of 10^{-7} per year. This is the product of multiplication of the initiating event probability with the probability of a single missile hitting the HxB. ONR acknowledged that the probabilistic aspects of the safety case should be stated, but should not influence the deterministic case. ONR's expectation is that the safety case should be based on a robust deterministic case.
- Based on a single missile hitting the HxB, Hitachi-GE considers that at least one division of RCW and RSW would remain available following a turbine disintegration event. The availability of safety divisions following turbine disintegration (in the Hx/B and elsewhere) is strongly dependent on the assumptions made (angle of trajectories, number of fragments and energy of those fragments).
- Hitachi-GE assumes that more than one high-energy missile hitting the Hx/B, or other buildings, within the GDA plot plan, is a Beyond Design Basis event. Evidence to support this assertion has not been provided. In the event of total loss of Hx/B, the Backup Building provides the requisite function.
- Hitachi-GE identified that a number of defence in depth provisions are in place (turbine casing, Turbine Building *T/B), and target building reinforced concrete walls), however, insufficient confidence exists to establish a formal safety case claim on mitigating a high energy turbine missile.
- Hitachi-GE proposed to undertake an optioneering study as part of an ALARP study to consider alternative Hx/B location and layout, capability of Hx/B and T/B structure and increase in turbine case thickness/ strength, but indicated that Hx/B site layout optimisation may be difficult at GDA state.
- ONR's expectation is that a robust deterministic safety case should be developed based on buildings site layout optimisation against turbine disintegration. This should include adequate segregation of SSCs in different buildings, and /or withstand capability of building structures.

Regulatory Expectation

Hitachi-GE has made limited overall progress in this area and ONR's concerns are largely outstanding.

ONR's expectation is that a robust deterministic safety case shall be developed and cohesive claims, arguments and evidence shall be presented. Hitachi-GE shall address the following:

- The proposed safety case is based on the assumption that a DB event will involve a single missile impacting the Hx/B damaging a single division, whereas a BDB event will involve all three divisions of RSW / RCW cooling in the Hx/B being destroyed by one or several high energy missiles. Substantiation of these claims is required reflecting ONR's SAPs FA.2, FA.5, AV2, AV.3, AV6, and

EMC and ECS series as appropriate.

- The HxB has not been optimised against turbine disintegration as it is located within the direct strike of a missile. The Hx/B building design appears to provide protection for each train of SSC delivering the key safety functions by segregation within the building in line with ONR's SAP EDR.2. However, the segregation provided within the Hx/B appears inadequate to protect the SSCs housed in the Hx/B from internal hazards initiated outside the building and capable to disable more than one train of SSC (SAP ESS.18).
- The safety case shall address unavailability of SSCs in line with ONR's SAPs ESS.23 and ESS.25.
- Defence in depth arguments shall be presented in line with ONR's SAP EKP.3.
- Consideration of all relevant buildings in addition to Hx/B shall be given.
- Consequential hazards shall be presented.
- Demonstration of ALARP, including evidence of appropriate optioneering of all various options eg relocation of the HxB to a favourable location, provision of safety trains in alternative locations, strengthening the walls of buildings, and etc.

References

1. UK-ABWR Topic Report on Internal Missiles Rev. 1, GA91-9201-0001-00094, AE-GD-0264 Re. 1, May 2015

2. Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants. International Atomic Energy Authority IAEA NS-G 1.11

3. Regulatory Guide 1.206 Regulatory Position Part I: Standard Format and Content of Combined License Applications C.I.3 Design of Structures, Systems, Components, and Equipment

   Regulatory Guide 1.115, Protection Against Turbine Missiles

   NUREG-0800 - Standard Review Plan, 3.5.1.3, Turbine Missiles

Regulatory Observation Actions

RO-ABWR-0079.A1

- A1.1 Clearly define and substantiate the number of missiles generated by a turbine disintegration event, and impact with buildings, during DB and BDB events.
  - The methodology, data and assumptions used in the analysis to derive the number of missiles generated and impact with buildings shall be presented together with appropriate sensitivity studies.
  - This shall include a justification of the assumed 25 degree of direct missile strike. Appropriate sensitivity studies shall be presented.
- A1.2. Develop a robust deterministic safety case by:
  - Systematic identification and quantification of consequences for all relevant buildings, including consequential hazards such as fire, flooding, steam release and etc.
  - Addressing common cause failure and cliffe edge effects.
  - Reflecting all plant states and equipment unavailability.
  - Presenting appropriate claims, arguments and evidence.
  - Presenting defence in depth arguments.
- A1.3 Provide an ALARP justification that includes:
  - Evidence of optioneering studies on plant layout, separation/ segregation, redundancy, structural

strengtening of buildings and other protection measures to eliminate or reduce the risk to ALARP. **Resolution required by to be determined by Hitachi-GE Resolution Plan** _____

REQUESTING PARTY TO COMPLETE	
Actual Acknowledgement date:	
RP stated Resolution Plan agreement date:	