REGULATORY OBSERVATION

REGULATOR TO COMPLETE

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Date sent:	15th August 2016
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Agreement of Resolution Plan Required by:	*To be determined by Hitachi-GE Resolution Plan*
Resolution of Regulatory Observation required by:	*To be determined by Hitachi-GE Resolution Plan*
TRIM Ref.:	2016/323037
Related RQ / RO No. and TRIM Ref. (if any)**:**	RO-ABWR-0016 (Trim Ref. 2014/253045); ; RO-ABWR-0037 (Trim Ref. 2015/20684); RO-ABWR-0044 (Trim Ref. 2015/59719); RO-ABWR-0054 (Trim Ref. 2015/181094); RO-ABWR-0064 (Trim Ref. 2015/390811); RQ-ABWR-0083 (Trim Ref. 2014/118093); RQ-ABWR-0781 (Trim Ref. 2016/88145); RQ-ABWR-0782 (Trim Ref. 2016/88165); RQ-ABWR-0783 (Trim Ref. 2016/88184); RQ-ABWR-0784 (Trim Ref. 2016/88221); RQ-ABWR-0785 (Trim Ref. 2016/88247); RQ-ABWR-0786 (Trim Ref. 2016/88273); RQ-ABWR-0787 (Trim Ref. 2016/88303).
Observation title:	Robust demonstration that the design of the UK ABWR off-gas system reduces risks SFAIRP
Technical area(s) 9. Reactor Chemistry 10. Radiation Protection & (Level 3 PSA) 11. Mechanical Engineering 15. Radwaste & Decommissioning 21. Generic Environmental Permitting	**Related technical area(s)** 4. PSA 5. Fault Studies 10. Radiation Protection & (Level 3 PSA)

Regulatory Observation

SUMMARY

The objective of this Regulatory Observation (RO) is to state ONR's expectations with respect to Hitachi-GE producing a robust demonstration that the design of the UK ABWR off-gas system reduces risks So Far As is Reasonably Practicable (SFAIRP).

The UK ABWR off-gas system is designed to control and mitigate a number of hazards arising during normal operations, including, the accumulation of radioactivity (predominately radioisotopes of xenon and krypton), and explosion hazards from hydrogen generated by radiolysis. The off-gas system purposefully accumulates radioactivity in order to delay the release of radioactive noble gases to the atmosphere, thus allowing radioactivity to decay to acceptably lower levels, prior to its discharge.

This means the off-gas system is a principal discharge route to atmosphere during normal operations. As such, in producing a robust ALARP[1] demonstration, Hitachi-GE will also need to take account of legislation regulated by the Environment Agency, where the requirement to apply Best Available Techniques (BAT) to discharges and disposals of radioactive waste applies. This RO has therefore been raised jointly by ONR and the Environment Agency.

[1] The terms ALARP and SFAIRP can be used interchangeably. The outcome of reducing risks SFAIRP is that the level of risk is ALARP *i.e.* the outcomes are the same.

As the Generic Design Assessment (GDA) of UK ABWR has progressed, ONR has raised Regulatory Observations (RO) and Queries (RQ), to either directly or indirectly, request further information from Hitachi-GE to underpin the design and safety case for the off-gas system. Hitachi-GE has produced, and continues to produce, responses to these ROs and RQs and has already committed to further work to demonstrate the design of the UK ABWR off-gas system reduces risks SFAIRP.

ONR's on-going, multi-disciplinary assessment, of the off-gas system has, however, revealed a number of gaps between Hitachi-GE's submissions and regulatory expectations. This RO has therefore been raised to ensure regulatory expectations are clearly understood. Until a robust demonstration has been provided, which takes account of all relevant risks which the UK ABWR off-gas system is required to control and mitigate; ONR cannot form a judgement on whether the design of the off-gas system ensures the legal duty of controlling risks and reducing risks SFAIRP will be met.

BACKGROUND

Boiling Water Reactors (BWRs) are direct cycle nuclear power plants, which means some of the coolant water and moderator passing through the Reactor Pressure Vessel (RPV) boils and is passed directly through the main steam lines to the turbine. This is different to other civil nuclear power plants in operation in the United Kingdom (UK) today, where the gas or liquid coolant is contained in a primary circuit, which rejects heat to a secondary circuit containing water, which then boils to produce steam (*i.e.* indirectly).

The objective of GDA is not to compare the designs of direct and indirect cycle nuclear power plants, however, the direct cycle nature of how BWRs operate has a number of important consequences for the risks and hazards which the off-gas system of BWRs need to be designed to safely manage and control. For example, the radioactivity hazard arising from the accumulation of volatile species present in the reactor coolant during normal operations, including radioisotopes of the noble gases xenon and krypton, and also the hazards arising from the accumulation of hydrogen generated from the radiolysis of the water coolant, will also be present in the steam which leaves the RPV and enters the off-gas and turbine systems, respectively.

To control and mitigate these potential hazards the UK ABWR design features an off-gas system. The off-gas system extracts non-condensable gases (including hydrogen) from the condenser and treats it to remove hydrogen, by recombination to water, and radioactive noble gases by adsorption onto temperature controlled charcoal beds. The treated gas is then directed to the plant stack for discharge.

This means, like other BWRs, the UK ABWR off-gas system will accumulate an appreciable inventory of radioactivity, predominately in the form of radioisotopes of the noble gases xenon and krypton. The off-gas system also processes significant quantities of hydrogen under normal operations.

An important consideration requiring increased regulatory scrutiny is that the off-gas system is located outside of the main containment vessel (the Reinforced Concrete Containment Vessel (RCCV)). Given one of the main functions of the system is to purposefully accumulate radioactivity, this has important consequences for the assessment of risk from the UK ABWR, as the off-gas system represents a potential source of increased radioactivity available for release to the environment should the system fail to perform as intended or due to fault scenarios. ONR therefore need to be satisfied the design and operation of the UK ABWR off-gas system represents Relevant Good Practice (RGP) and that all reasonably practicable measures have been taken to reduce relevant risks to ALARP.

For clarity, a schematic of the current design of the UK ABWR off-gas system is provided below:

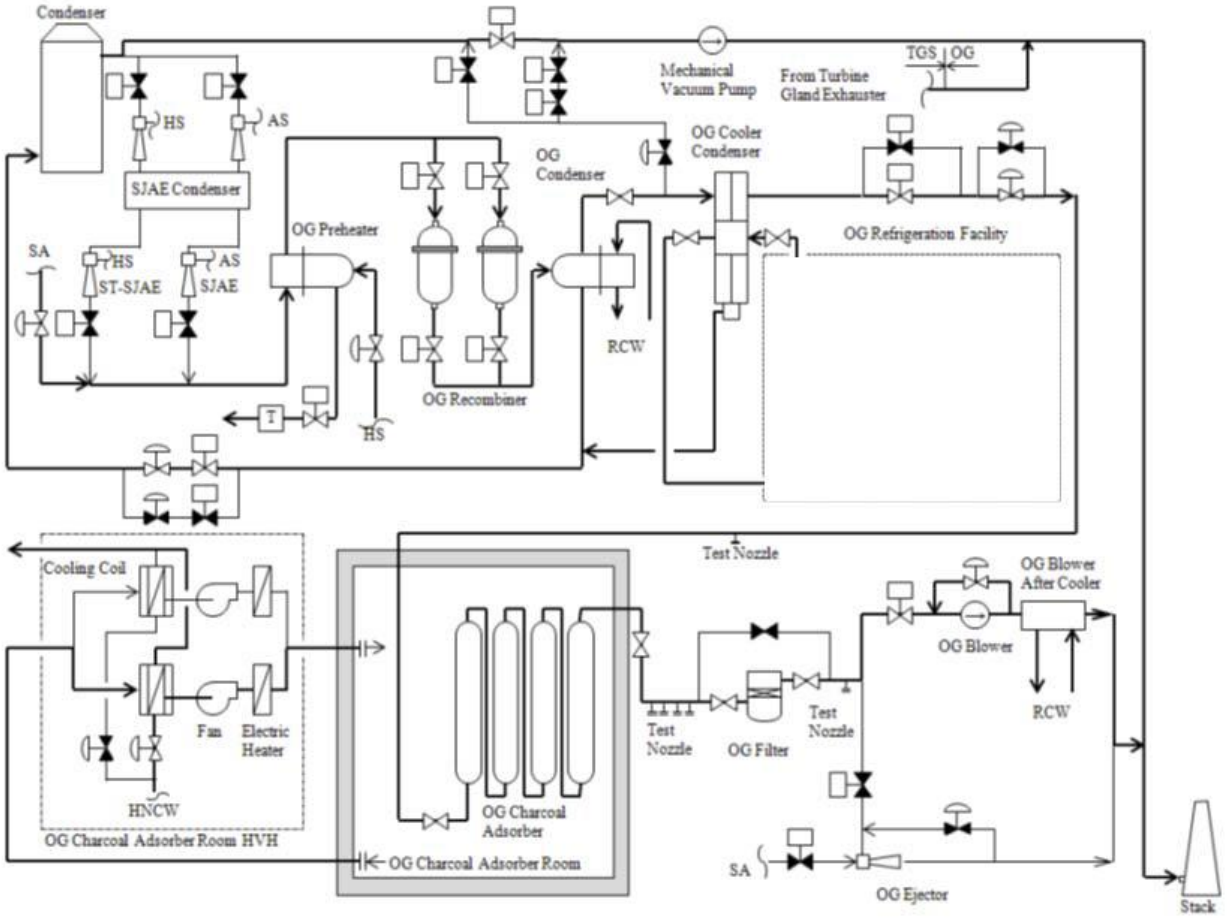

Figure 1: Schematic of the current design of the UK ABWR off-gas system [1]

Throughout GDA, a number of ONR technical disciplines, including, but not limited to: reactor chemistry, mechanical engineering, radwaste & decommissioning and radiation protection, have raised several ROs; not necessarily specifically focussed on the design of the off-gas system, but on matters which mean the off-gas system design needs to be explicitly considered and justified, to provide a satisfactory response. These ROs are, namely:

1. RO-ABWR-0017 [2] – on the topic of nuclear ventilation codes and standards; led be mechanical engineering;
2. RO-ABWR-0036 [3] – on the topic of producing a robust justification that the approach to managing solid, liquid and gaseous radioactive wastes for UK ABWR, reduces risks SFAIRP; led by radwaste & decommissioning;
3. RO-ABWR-0044 [4] – on the topic of demonstrating the UK ABWR has been designed safely manage radiolysis gases generated under normal operations; led by reactor chemistry.
4. RO-ABWR-0064 [5] – on the topic of identifying and providing UK ABWR design features (permanent & temporary) necessary to provide adequate control of radioactive contamination; led by radiation protection.

In response to these ROs, Hitachi-GE has produced a number of submissions (in-line with their resolution plans) which sit within the hierarchy of UK ABWR safety case documentation, including:

- A Basis of Safety Case (BoSC) for the off-gas system [6];
- A Topic Report on ‘ALARP Assessment for the Off-gas System [7], and;
- A Topic Report on ‘Safe Management of Radiolytic Gases Generated Under Normal Operations’ [8].

ONR has undertaken assessment of various revisions of all three of these submissions and have raised related RQs [9]; a number of them pertaining directly to the design, and justification thereof, for the off-gas

system. Overall, Hitachi-GE's submissions and responses to date demonstrate they are going some way to addressing the intent of the above ROs and also demonstrate they are undertaking on-going work, specifically for the off-gas system, to identify and implement reasonably practicable measures to further reduce risk.

Despite this, gaps still remain and ONR has identified some specific reservations (addressed by the Regulatory Observation Actions attached to this RO) with the approach being taken by Hitachi-GE to justify the design of the off-gas system, overall, is ALARP. For example, when considering the design of BWR (and similar systems for other reactor technologies) off-gas systems, there are several different options which could be implemented. For example, with specific reference to **Figure 1** above:

- Some BWRs have a 'guard bed' installed upstream of the charcoal adsorbers to protect the beds from the deleterious effects of moisture ingress;
- Charcoal adsorber beds could be arranged in series, in parallel and/or be segregated;
- The operating temperature of the charcoal adsorber beds (therefore design of the system) has important implications for the performance of the off-gas system;
- Different design and operational considerations for off-gas systems may provide different hold-up (decay) times for krypton and xenon radioisotopes.

So far, Hitachi-GE has not provided responses which demonstrate adequate consideration has been given to these, and other factors, to demonstrate the overall design of the UK ABWR off-gas system is ALARP.

In addition, ONR considers the basis for some of the arguments put forward by Hitachi-GE to justify the current off-gas system design, can be readily challenged. This includes the way in which Hitachi-GE's 'non-reactor' categorisation and classification scheme for Structures, Systems and Components (SSCs) has been applied to the off-gas system. This RO has therefore been raised to make regulatory expectations clear and to explicitly highlight the gaps, in ONR's view, which remain in Hitachi-GE's submissions.

REGULATORY EXPECTATIONS

ONR expect the ALARP demonstration prepared in response to this RO to provide a justification that the design of the off-gas system, overall, controls and mitigates all relevant plant risks. There are therefore a number of overlaps with the responses being prepared for ROs-0017, -0036, -0044 and -0064, and potentially other ROs and/or on-going work. ONR would expect all relevant interfaces to be appropriately considered. This RO is not intended to replace or change any requirements or expectations given in these existing ROs, rather, ONR expect the response to this RO to be consistent with the work being performed elsewhere. The response to this RO should therefore be viewed as a higher-level, overarching demonstration, that the overall design of the UK ABWR off-gas system reduces risks to ALARP.

For clarity, ONR's view on the interfaces with these ROs is that generally, they are at a lower, more detailed level, when compared to the demonstration being requested by this RO. ONR's view is that on-going work and work already completed, to respond to these ROs, should provide inputs into the overall ALARP case for the off-gas system, being requested under this RO. For example, for RO-0017, this would provide relevant inputs from a mechanical engineering perspective on what constitutes RGP for the design of ventilation systems for nuclear installations. For RO-0036, this would provide relevant inputs focussing specifically on issues related to radioactive waste management. RO-0044 would provide input information on hydrogen hazards. RO-0064 would provide input information on specific design features identified for the off-gas system which are necessary to control radioactive contamination.

One of the main sources of standards and guidance ONR use in assessing the UK ABWR design are the Safety Assessment Principles (SAPs) [10]. As outlined in SAP EKP.1, the engineering key principle covering inherent safety, ONR's preference is for an inherently safe design. Achieving an inherently safe design can be aided by reducing the inventory of potentially harmful substances to the minimum necessary to achieve the required safety function, and/or by controlling the physical state of harmful substances to remove or minimise their potential effects. The application of this principle is particularly important for a new facility, at the design stage.

The regulators (ONR and the Environment Agency) expect Hitachi-GE to provide a robust demonstration that the design of the UK ABWR off-gas system has been optimised and is appropriately balanced, when taking account of the legislative requirements to reduce risks to ALARP and minimise discharges of radioactive waste

to the environment, by applying BAT.

ONR's expectations with respect to demonstrating ALARP are given in NS-TAST-GD-005 [11]. The Health and Safety Executive (HSE) have also published (online) a suite of guidance on ALARP [12]:

ONR expect Hitachi-GE to take due account of the principles and guidance set out in these documents when preparing their ALARP demonstration for the design of the UK ABWR off-gas system. More specifically, ONR would expect Hitachi-GE to include the following:

a) **Relevant Good Practice (RGP):** ONR expects Hitachi-GE to apply RGP as a minimum. 'Relevant' means it should be appropriate to the activity and associated risks, and should be up to date. ONR will form a judgement by comparing Hitachi-GE's proposed design for the off-gas system against RGP and good design principles. The use of good practice at the design stage is essential to demonstrating the achievement of ALARP.

   As a guide, Hitachi-GE should aim and compare against levels of safety that are known to have been achieved in other designs. ONR expect that UK ABWR would not give rise to a risk level greater than that achieved by existing practice for comparable functions. Where others are achieving a higher standard, ONR will challenge Hitachi-GE whether this standard is, in effect, good practice.

   A universal practice adopted for BWR and ABWR off-gas system design may not necessarily be good practice or reduce risks to ALARP and Hitachi-GE should not assume that it is. What is good practice may cease to be relevant with the passage of time and new technology may make a higher standard reasonably practicable.

b) **Options and optioneering:** For UK ABWR a selection amongst options for the design of the off-gas system will be needed.

   An effective approach for demonstrating that risks are ALARP is to start with the safest option within the range of practicable solutions. This option should be chosen by Hitachi-GE unless they can show it is not reasonably practicable; in which case attention should pass to the next safest option. There should also be a comparison of the chosen option with current good practice to confirm that residual risks are no greater than existing BWRs or ABWRs. Where necessary, there should also be a robust demonstration of gross disproportion in terms of cost (time, trouble, money), supported by well-reasoned argument(s) and suitable and sufficient evidence.

   ONR will form a judgement as to whether the design of the off-gas presented for UK ABWR reduces risks to ALARP based on our knowledge as a regulator, including: knowledge of relevant good practice in the area, ONR's knowledge of other possible options, and our judgement of the arguments and evidence presented in Hitachi-GE's case.

   To aid transparency in the ALARP demonstration, ONR would expect Hitachi-GE to record the range of options considered and discarded. ONR expect the ALARP demonstration to be made in an appropriate place in the safety case for UK ABWR.

c) **Known problem areas:** The ALARP demonstration should set out how known problem areas (e.g. identified from Operational Experience Feedback (OEF), improved analysis, or improving standards) have been addressed and how and why the particular option, or solution chosen, was arrived at.

d) **Proper balancing of all risks:** ONR expects Hitachi-GE to use good practice which will be relevant to the risks from operating UK ABWR and to cover all risks.

   The ALARP argument needs to consider all types of risk that are relevant and where these conflict with one another, ensure that an appropriate overall balance is achieved in regard to the their management. Risk should be considered over the life of the facility and all affected groups taken account of. The potential scale and nature of risks considered needs to be clearly presented.

e) **Taking cognisance of all relevant legislation:** Hitachi-GE will have to select an option taking account of legislation regulated by ONR and also the Environment Agency, where the requirement to apply Best Available Techniques (BAT) to discharges and disposals of radioactive waste applies. ONR would therefore expect Hitachi-GE to arrive at an 'optimised' solution, where the UK ABWR design will

be capable of best meeting the requirements of all relevant legislation.

f) **Uncertainties and the precautionary principle:** Where the potential radiological consequences are high, ONR would expect Hitachi-GE to take a precautionary approach by giving more weight to the use of sound engineering and operational practice rather than arguments about the probability of failure. The essence of the precautionary approach is essentially that precautions should be taken unless there is a good reason to think that the risk is insignificant.

Thought should also be given to the robustness of the conclusions of the ALARP demonstration with respect to uncertainties and to any assumptions employed in the demonstration. Where a case uses quantitative methods sensitivity studies to test the robustness of the arguments should be provided.

References:

[1] UK ABWR GDA, *Generic PCSR Sub-chapter 18.3: Off-gas Radioactive Waste Management System*, Revision B, Hitachi-GE, 2015. http://www.hitachi-hgne-uk-abwr.co.uk/downloads/2015-10-30/UKABWR-GA91-9101-0101-18003-RevB-PB.pdf
[2] Regulatory Observation RO-ABWR-0017, *Nuclear Ventilation Codes and Standards*, ONR, September 2014. http://www.onr.org.uk/new-reactors/uk-abwr/reports/ro-abwr-0017.pdf
[3] Regulatory Observation RO-ABWR-0036, Demonstration that the Approach Taken to Radioactive Waste Management Reduces Risks SFAIRP, ONR, January 2015. http://www.onr.org.uk/new-reactors/uk-abwr/reports/ro-abwr-0036.pdf
[4] Regulatory Observation RO-ABWR-0044, Demonstration UK ABWR has been Designed to Safely Manage Radiolysis Gases Generated Under Normal Operations, ONR, March 2015. http://www.onr.org.uk/new-reactors/uk-abwr/reports/ro-abwr-0044.pdf
[5] Regulatory Observation RO-ABWR-0064, *Design Approach to Identification and Provision of Permanent and Temporary Features Necessary for the Adequate Control of Radioactive Contamination Across the Full Lifetime of UK ABWR,* ONR, November 2015. http://www.onr.org.uk/new-reactors/uk-abwr/reports/ro-abwr-0064.pdf
[6] UK ABWR GDA, *Off-gas System Basis of Safety Case*, Revision 3, Hitachi-GE, November 2015. TRIM 2015/454350.
[7] UK ABWR GDA, *Topic Report on ALARP Assessment for Off-gas System,* Revision 2, Hitachi-GE, December 2015. TRIM 2015/474059.
[8] UK ABWR GDA, *Topic Report on Safe Management of Radiolytic Gases Generated Under Normal Operations,* Revision 1, Hitachi-GE, January 2016. TRIM 2016/42207.
[9] Regulatory Queries RQ-ABWR-0782 -0787, ONR, February 2016. TRIM 2016/88145, 2016/88165, 2016/88184, 2016/88221, 2016/88247, 2016/88273, 2016/88303.
[10] Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0, ONR. http://www.onr.org.uk/saps/
[11] Technical Assessment Guides, Guidance on the Demonstration of ALARP, NS-TAST-GD-005, Revision 6, ONR, September 2013. http://www.onr.org.uk/operational/tech_asst_guides/index.htm
[12] Principles and Guidelines to Assist HSE in its Judgements that Dutyholders have Reduced Risk as Low as Reasonably Practicable;
Assessing Compliance with the Law in Individual Cases and the use of Good Practice;
Policy and Guidance on Reducing Risks as Low as Reasonably Practicable in Design. HSE Principles for Cost Benefit Analysis in Support of ALARP Decisions;
HSE – Risk Management: ALARP at a Glance;
HSE – Risk Management: Cost Benefit Analysis (CBA) Checklist.

http://www.hse.gov.uk/risk/theory/alarpglance.htm

Regulatory Observation Actions

RO-ABWR-0073.A1 – Hitachi-GE to provide a robust demonstration to show that the design of the UK ABWR off-gas system reduces relevant risks SFAIRP, taking due account of actions under this and related ROs.

ONR expect Hitachi-GE to demonstarte a process of optimisation has been followed for the design of the off-gas system. This should include appropriate application of Hitachi-GE's categorisation and classification

scheme for 'non-reactor' SSCs. The process of optimisation should be demonstrated to ONR in a transparent manner, and form part of the safety case for UK ABWR.

More specifically, in response to this Action, ONR expect Hitachi-GE should:

(1) Identify and describe what the risks are that are being eliminated, reduced and/or mitigated (including likelihood and consequences);
(2) What measures are in place to eliminate, reduce or mitigate these risks, including the adoption of relevant good practice measures;
(3) Identify what options, or range of options, could be applied to further mitigate these risks;
(4) A demonstration of whether these options are reasonably practicable to implement or not, supported by robust arguments and suitable and sufficient evidence;
(5) Consideration of any residual detriment and a demonstration the overall design of the off-gas system reduces relevant risks SFAIRP.

In perfroming the above, ONR expects Hitachi-GE to take due account of relevant Worldwide OPEX and to indetify and consider good practice in design, opertional and engineering practices, implemented for other BWR off-gas system designs.

ONR expect that the expectations given above, in addition to the requirements stated in relevant ONR guidance and explcitly referred to in this RO, will be included in the submission provided in response to this Action.

The response to this Action may be combined with any other Action under this RO, if deemed appropriate. The response should include, or reference, submissions made or planned, under other ROs.

RESOLUTION REQUIRED BY: **to be determined by the Hitachi-GE resolution plan.**

RO-ABWR-0073.A2 – Hitachi-GE to provide an evaluation of the off-gas system design for UK ABWR against RGP and the hazards defined under Action 1, to identify whether any reasonably practicable improvements can be made to reduce risks SFAIRP.

As an input into Action 1, ONR expect Hitachi-GE to undertake an evaluation of the UK ABWR off-gas system design and provide a robust justification that the design represents RGP. ONR expect this evaluation to include the consideration of making any reasonably practicable improvements to the UK ABWR off-gas system design.

The response to this Action may be combined with any other Action under this RO, if deemed appropriate.

RESOLUTION REQUIRED BY: **to be determined by the Hitachi-GE resolution plan.**

RO-ABWR-0073.A3 – Hitachi-GE to provide a robust demonstration to show the design of the UK ABWR off-gas system provides adequate containment of radioactive materials and radioactive wastes, SFAIRP.

As an input and as part of Action 1, ONR expect Hitachi-GE to demonstrate how the design of the UK ABWR off-gas system is able to control the containment of radioactive materials and radioactive wastes, to either prevent or detect, their leakage or escape, SFAIRP. The scope of this demonstration includes normal operations and consideration of any 'non-reactor' fault scenarios which give rise to the potential for leakage and/or escape of radioactive material or waste.

More specifically, in response to this Action, ONR expect Hitachi-GE should:

(1) Identify and describe the measures in place to eliminate, or prevent, leakage or escape from the off-gas system primary containment;

(2) Identify and describe any systems designed to detect, locate, quantify and monitor any leakage or escape that may occur from the off-gas system primary containment boundaries;
(3) Provide a demonstration an appropriate balance has been struck between the provision of primary preventative measures and secondary measures, to mitigate leakage or escape;
(4) Describe how the potential for human error to give rise to a leakage or escape, has been minimised, SFAIRP;
(5) Consider all 'non-reactor' fault scenarios which may give rise to a leakage or escape. This should include adequate consideration of both acute and chronic scenarios.

The response to this Action may be combined with any other Action under this RO, if deemed appropriate.

RESOLUTION REQUIRED BY: to be determined by the Hitachi-GE resolution plan.

RO-ABWR-0073.A4 – Hitachi-GE are required to demonstrate and document that the optimised design of the off-gas system is BAT during its considerations in response to all other actions of this RO.

As an output of Actions 1 and 2, if, in providing the robust ALARP demonstration requested by this RO, or in other referenced ROs, Hitachi-GE identify any further, reasonably practicable measures that should be implemented for the off-gas system, the Environment Agency expect Hitachi-GE to present a clear and logical description and justification of these changes in the UK ABWR GEP documentation.

More specifically, in response to this Action, the Environment Agency expect Hitachi-GE should:

(1) Discuss the factors considered in demonstrating the UK ABWR off-gas system design is balanced and optimised, considering the requirements to both demonstrate risks are ALARP and apply BAT for discharges;
(2) Where necessary, give due consideration to discharges and environmental factors and reflect these considerations in all relevant GEP documentation.

The response to this Action may be combined with any other Action under this RO, if deemed appropriate.

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:	