REGULATORY OBSERVATION

REGULATOR TO COMPLETE

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Related RQ / RO No. and TRIM Ref. (if any)**:**	
Observation title:	Source Terms
Technical area(s) 9. Reactor Chemistry GEP	**Related technical area(s)** 5. Fault Studies 10. Radiation Protection (& Level 3 PSA) 12. Structural Integrity 15. Radwaste & Decommissioning

Regulatory Observation

BACKGROUND

This Regulatory Observation (RO) is associated with the definition of and evidence that will be necessary to justify the "source terms" for the UK ABWR design during "operational states" [1] and "expected events" [2]. This will ultimately support the requirement that the risks associated with radioactivity in UK ABWR have been reduced So Far As Is Reasonably Practicable (SFAIRP).

This RO and associated Regulatory Observation Actions (ROA) sets out the regulators' (ONR and Environment Agency) expectations regarding the use of source terms for operational states in UK ABWR during GDA. The entire scope of the regulators' interest in the topic of source terms extends beyond the boundary of this RO, to design basis and severe accidents. However, with the exception of Actions 3, 7, 8 and 9 that deal with the management of source term information, this RO is concerned with operational states and not accident conditions.

Ultimately the regulators expect a demonstration that the source terms for UK ABWR during operational states have been reduced So Far As Is Reasonably Practicable (SFAIRP) and that Best Available Techniques (BAT) has been applied. The responses to this RO should include the development, definition and justification of the source term(s) used.

REGULATORY EXPECTATIONS

The definition and appropriate use of the "source term" is important in understanding, and therefore controlling, the hazards posed by any nuclear facility.

IAEA have defined the "source term" as [1]: *Source term - The amount and isotopic composition of material released (or postulated to be released) from a facility.* This is slightly broader than the definition found in the SAPs [3], which considers source terms in the context of accident analysis.

However, it is important to stress that for GDA of UK ABWR, ONR and the Environment Agency will be considering both the form of the source term and its application during operational states (and accident conditions, including severe accidents, outside of this RO). In this respect the description of

the term “source term” is broader; it is not limited to only considering material released (or discharged) from a UK ABWR. For the purpose of this RO the following definition of “source term” is therefore applicable:

> *Source term - The types, quantities, and physical and chemical forms of the radionuclides present in a nuclear facility that have the potential to give rise to exposure to radiation, radioactive waste or discharges.*

This therefore makes source terms a broad topic of interest to ONR inspectors in the reactor chemistry, radiation protection, radwaste and decommissioning and fault studies areas. The Environment Agency assessors are interested in source terms from the perspective of radioactive discharges and ensuring that Best Available Techniques (BAT) has been applied in the minimisation of radioactive wastes and discharges.

The regulators would expect that the source terms for the UK ABWR design should be evaluated for operational states for a number of reasons, including:

(a) To ensure that the design is optimised such that the source terms are reduced SFAIRP;

(b) To demonstrate that consequential hazards such as radiation doses, generation of radioactive waste and discharges are also reduced SFAIRP and apply BAT respectively; and,

(c) To demonstrate that the design ensures that numerical targets and legal limits, including restrictions on doses, are met.

The regulators recognise that the chemistry regime and material choices being offered for UK ABWR may be different to the Japanese standard ABWR and therefore expect Hitachi-GE to identify all relevant features of the design in the presentation of their responses to the ROAs described below.

On the completion of the ROAs associated with this RO, ONR and the Environment Agency would expect Hitachi-GE to have provided a robust description and justification for the source terms for the UK ABWR design during operational states, and to have presented it in their safety and environmental cases.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection, 2007 Edition, IAEA, Vienna (2007).

[2] *Process and Information Document – Generic Design Assessment*. Version 2. Environment Agency. March 2013. http://cdn.environment-agency.gov.uk/LIT_7998_3e266c.pdf

[3] *Safety Assessment Principles for Nuclear Facilities*. 2014 Edition Revision 0. ONR. November 2014. www.onr.org.uk/SAPS/saps2014.pdf.

[4] *Topic Report 1: Definition of the UK ABWR Design Source Term*, GA91-9201-0001-00107, HE-GD-5088, Revision 0. Hitachi-GE. 15 January 2015. TRIM Refs 2015/20329, 2015/20332, 2015/20334 and 2015/20338.

Regulatory Observation Actions

RO-ABWR-0006.A1 – Hitachi-GE are required to define the source term(s) for the UK ABWR design during operational states.

RESOLUTION REQUIRED BY - As defined by Resolution Plan

BACKGROUND

In order to evaluate the source term(s) for a nuclear power plant, it is necessary to understand the sources of radiation, to evaluate the inventories and to know the mechanisms by which that material could be transferred throughout the plant and ultimately be released to the environment.

There are essentially two mechanisms which lead to the production of radionuclides in a BWR. The first of these is fission of fuel material. This is nominally contained within the fuel cladding, but defects can occur during operational states and the consequences on the source terms should be assessed. The second mechanism for the production of radionuclides is via activation of other materials that enter the core radiation field. These include structural elements in or around the core, the coolant (either water itself or species dissolved in it) and, most importantly for radiation field control, transition metals present in corrosion products. In the absence of fuel defects the activation of the coolant and species dissolved in it account for the vast majority of activity within the primary coolant of an operational BWR. Therefore radioactivity carried by the coolant of a BWR is a:

- Principal source of Operator Radiation Exposure (ORE);
- Principal source of routine radioactive wastes and discharges;
- Contributor to the source term in some accidents, if they occur.

In the context of radiation sources, it is important to understand that a major source in a given operational state may become a minor one in a different operational state. Similarly, the importance may vary with the issue that is being addressed. Some isotopes that are of minor importance for dose rate considerations during operation become of major importance during decommissioning. Also, even when dealing with reactors of the same type, changes in the design may have a strong influence on the relative importance of different sources.

The regulators therefore consider that an adequate definition and justification for the source term(s) for the UK ABWR design during operational states is an important part in delivering a meaningful GDA assessment.

REGULATORY EXPECTATIONS

The response to this ROA may be combined with other actions under this RO if considered appropriate.

The response to this ROA should consider all technical areas covered by this RO.

In response to this ROA, the regulators expect:

(a) Hitachi-GE to define the radionuclides present and their amounts within UK ABWR that constitutes the source term(s) during operational states, relevant to all technical areas covered by this RO including gaseous and liquid discharges. The source term(s) should consider both mobile and fixed sources of radioactivity (i.e. soluble within the coolant or deposited on piping). Radioactivity confined within the fuel need not be considered here.

(b) This definition should be based upon the design and operations of the plant and should also consider how the nature and quantity of this radioactivity may change and evolve over the lifetime of the plant.

(c) The source term should include all appropriate radioactive sources generated within the plant, including fission products, radioactive corrosion products, activation products in coolant and impurities, and actinides. Hitachi-GE should identify any exclusion from their source term(s) and the reasons for there omission (for example, negligible impact or production).

(d) The definition of the source term(s) should consider all operational states, including transient conditions that may arise during transitions between states and, in the source term for gaseous and liquid discharges, any expected events. It is likely that more than one source term will need to be defined to cover all of these different situations.

(e) Hitachi-GE to consider the source term(s) within all of the systems in which radioactivity is expected to be present within the design. Hitachi-GE should identify the controls (physical and procedural) needed to prevent the source term from growing to potentially unacceptable levels (which should also be defined), and to demonstrate to the regulators that this process can be managed and controlled during the reactor lifetime and should provide details of;

    i. The controls (both physical and procedural, whether formalised or not on current

plants) that prevent radioactivity spreading through these systems;

ii. The controls that will monitor any spread, should it occur;

iii. The features needed to remove excessive levels of activity should they arise; and

iv. Justification of the sizing of clean-up facilities to deal with the anticipated activity arisings.

RO-ABWR-0006.A2 – Hitachi-GE are required to demonstrate the adequacy of the source term(s) used across the different technical areas.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

This ROA is concerned with the level of justification and evidence provided to support the defined source term(s) for the UK ABWR design, under Action 1 of this RO.

It is important that an adequate and robust justification, with sufficient supporting evidence, is provided for the source term(s) for the UK ABWR design. Ideally, the evidence should be appropriate, applicable and directly relevant to the UK ABWR, however the regulators recognise that this may not always be possible and it then becomes important to justify the processes, judgements and assumptions applied to make it so. This evidence could include plant data, modelling, estimates and assumptions.

The regulators consider that an adequate resolution of this ROA is important to delivering a meaningful GDA assessment for UK ABWR.

REGULATORY EXPECTATIONS

The response to this ROA should provide a robust justification for the UK ABWR source term(s) defined under Action 1 of this RO.

The response to this ROA may be combined with other actions under this RO if considered appropriate.

The response to this ROA should consider all technical areas covered by this RO.

In response to this ROA, the regulators expect:

(a) Hitachi-GE to demonstrate that the evidence used to support the source term(s) is:

i. Applicable to the UK ABWR design, or if amended the assumptions used to make it so should be justified;

ii. Based upon a balanced mixture of appropriate supporting evidence, which could include plant data, modelling, estimates and assumptions.

(b) The justification and supporting evidence provided by Hitachi-GE should cover the entire scope of the source term(s) definition as given under Action 1 of this RO.

(c) Hitachi-GE to demonstrate the relevance and appropriateness of each strand of supporting evidence for its use in the safety and environmental cases for UK ABWR.

(d) Hitachi-GE to demonstrate independence of the different data sources and strands of evidence used to support the defined source terms.

(e) Appropriate evidence to be presented for all radionuclides that constitute the source term for gaseous and liquid discharges, covering all aspects of normal operation. Multiple strands of appropriate evidence are expected for each significant radionuclide. The evidence should be presented together with an explanation of its appropriateness for use in the environmental case for the UK ABWR.

RO-ABWR-0006.A3 – Hitachi-GE are required to demonstrate that the source term(s) have been used appropriately across the different technical areas.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

The definition and appropriate use of the source term is an important stage in understanding and deriving the safety requirements for any nuclear facility. This source term often takes the form of a radioactive inventory, plus any other parameters relevant to the particular activity. The regulators would expect the UK ABWR source terms to be used in a number of different ways in making the safety and environmental cases for the reactor design. In all of these areas the radioactive inventories may be manipulated to address a specific purpose.

To have confidence that the outputs of the environmental and safety reports are reliable it is important that the source term used in the design is consistent and adequately controlled. The specific details will be considered in the relevant assessment areas. In this ROA we are interested in the holistic approach to managing the source term.

REGULATORY EXPECTATIONS

The response to this ROA may be combined with other actions under this RO if considered appropriate.

In response to this ROA, the regulators expect:

(a) Hitachi-GE to describe how the source term is used and how this is modified to meet the requirements of the different technical areas, including:

   i. control of the source term information, including when it was derived and how it is updated;

   ii. details of any assumptions which could significantly affect the source term;

   iii. the assessments where the source term is used, and how;

   iv. how the source term has been used consistently across the assessment areas;

   v. how the source term has been manipulated for use in each specific assessment area, particularly any additional assumptions; and

   vi. how changes to the source term are managed and cascaded to the different assessment areas.

RO-ABWR-0006.A4 – Hitachi-GE are required to demonstrate that radioactivity in the UK ABWR design has been reduced SFAIRP during operational states, based upon the material choices.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

This ROA is concerned with the impact of material selection and treatments on the generation, accumulation and transfer of radioactive material in the UK ABWR design during operational states.

REGULATORY EXPECTATIONS

We recognise that a number of other factors can affect the selection of materials and treatments. Where a balance has been struck between risks associated with the generation and management of radioactivity and other safety concerns, these should be clearly stated and presented in the response.

The response to this ROA may be combined with other actions under this RO if considered

appropriate.

The response to this ROA should therefore cover all aspects of radioactivity related to the selection and treatment of materials in direct contact with the reactor coolant.

In response to this ROA the regulators expect;

(a) Overall, we expect to be provided with a justification and evidence for the selection of all key materials, from the perspective of measures which have been taken to reduce radioactivity SFAIRP. This should include all principle alloys in contact with the coolant (e.g. fuel cladding, feedwater system materials, RPV internals, auxiliaries which process and treat reactor coolant (i.e. reactor water treatment system) etc.) including weld metal equivalents.

(b) Hitachi-GE has indicated that the trace element content of alloys subjected to the neutron flux or reactor coolant in UK ABWR (e.g. RPV, feedwater alloys etc.) will be tightly controlled. The levels specified should be justified on an as low as reasonably practicable basis, thus demonstrating that the trace element content of materials and alloys in direct contact with reactor coolant has been reduced SFAIRP.

(c) Evidence that the use of alloys which contain significant quantities of elements which are prone to neutron activation (e.g. Ag, Sb etc.) has been reduced SFAIRP.

(d) Evidence that the manufacturing processes (including installation) has been optimised to minimise the generation of corrosion products and / or mitigate the accumulation of radioactive deposits SFAIRP.

(e) Evidence that the treatment of primary circuit alloys (e.g. heat treatment, surface finishing, surface treatments / coatings etc.) has been optimised to minimise the generation of corrosion products and / or mitigate the accumulation of radioactive deposits SFAIRP.

RO-ABWR-0006.A5 – Hitachi-GE are required to demonstrate that radioactivity in the UK ABWR design has been reduced SFAIRP during operational states, based upon the operating chemistry.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

This ROA is concerned with the impact of the operating chemistry on the generation, accumulation and transfer of radioactive material in the UK ABWR design during operational states.

REGULATORY EXPECTATIONS

We recognise that a number of other factors can affect the selection of the operating chemistry regime. Where a balance has been struck between risks associated with the generation and management of radioactivity and other safety concerns, these should be clearly stated and presented in the response.

The response to this ROA may be combined with other actions under this RO if considered appropriate.

The response to this ROA should therefore cover all aspects of radioactivity related to the operational chemistry.

The response to this ROA should consider all modes of operation.

In response to this ROA the regulators expect;

(a) A demonstration that the operating chemistry regime has been optimised for the UK ABWR design to minimise the formation of radioactivity, fuel crud and corrosion products. This should include all additives (e.g. hydrogen, zinc, iron) and impurities (e.g. chloride, sulphate, silica etc.) in the reactor coolant. The effects throughout the entire circuit should be considered and the full operating cycle, including start-ups and shutdowns.

(b) Hitachi-GE should provide evidence of the effects of the proposed reactor coolant water

chemistry regime on fuel integrity considerations. This should include all additives and impurities in the reactor coolant. The effects of higher rated fuel channels and fuel elements within the core should also be considered.

(c) Hitachi-GE should provide justification and evidence that chemistry control, treatment, monitoring and dosing systems have been designed such that the effects of reactor coolant on radioactivity for the UK ABWR design have been minimised SFAIRP.

(d) Evidence that the reactor coolant chemistry proposed during start-up and shutdown periods has been optimised in terms of reducing radioactivity contained in the reactor coolant SFAIRP.

(e) Hitachi-GE should provide evidence of the affects of the proposed reactor coolant water chemistry regime on soluble radioactivity within the reactor coolant and radioactivity deposited on system pipework.

(f) Evidence that the reactor coolant chemistry proposed during commissioning and hot functional testing has been optimised in terms of reducing radioactivity contained in the reactor coolant or deposited on system pipework SFAIRP.

RO-ABWR-0006.A6 – Hitachi-GE are required to demonstrate that radioactivity in the UK ABWR design has been reduced SFAIRP during operational states, based upon the expected operational practices.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

This ROA is concerned with the impact of the operating practices on the generation, accumulation and transfer of radioactive material in the UK ABWR design during operational states.

REGULATORY EXPECTATIONS

We recognise that a number of other factors can affect the operating practices applied for the plant. Where a balance has been struck between risks associated with the generation and management of radioactivity and other safety concerns, these should be clearly stated and presented in the response.

The response to this ROA may be combined with other actions under this RO if considered appropriate.

The response to this ROA should consider all modes of operation.

In response to this ROA the regulators expect;

(a) Evidence that the operating practices which are necessary, expected or can be applied have been optimised in terms of reducing radioactivity contained in the reactor coolant or deposited on system pipework SFAIRP.

RO-ABWR-0006.A7 – Hitachi-GE are required to demonstrate that the response(s) to this RO will be adequately captured within the safety and environmental cases for the UK ABWR design.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

The purpose of this ROA is to ensure that the responses provided by Hitachi-GE under Actions 1 to 6 of this RO are adequately captured within the safety and environmental cases for UK ABWR.

REGULATORY EXPECTATIONS

We recognise a number of the themes and topics covered by the individual ROAs have key inter-dependencies, where there may be conflicting arguments and evidence presented in response to

each of the ROAs.

In response to this ROA the regulators expect:

(a) Hitachi-GE should identify the suitable submission(s) in which to present the overall response to this RO, for example in the Pre-construction Safety Report (PCSR) or Generic Environmental Permit (GEP), and justify how these will adequately capture the response(s) provided to the individual ROAs.

RO-ABWR-0006.A8 – Hitachi-GE are required to include any accident source terms derived from the Action 1 responses as part of their response to Actions 3 and 7.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

The safety case put forward by Hitachi-GE during Step 2 was based on distinct source terms for normal operational states and accident conditions. This led ONR to separate accident source terms from the scope of this RO. However, it is now likely that the radiological consequence assessment of some accidents may rely on source terms derived from those considered during normal operations (i.e. as defined under Action 1).

The purpose of this ROA is therefore to ensure that the responses provided by Hitachi-GE under Actions 3 and 7 of this RO adequately captured such related accident source terms, to ensure they are appropriately managed, controlled and included in the safety case for UK ABWR.

REGULATORY EXPECTATIONS

In response to this ROA the regulators expect:

(a) Hitachi-GE should confirm that they will capture any accident source terms derived from the Action 1 responses as part of their response to Actions 3 and 7.

RO-ABWR-0006.A9 – Hitachi-GE are required to ensure that the source terms defined under Action 1 are presented in the UK ABWR safety and environmental cases in an appropriate manner.

RESOLUTION REQUIRED BY – As defined by Resolution Plan

BACKGROUND

Hitachi-GE provided a response to RO-ABWR-0006.A1 in January 2015 [4]. This response defining the source terms is complex and large, at over 1300 pages. This in itself is not necessarily a problem. However, as a consequence of its size and presentation it is often difficult to follow and is unclear on what the most important considerations for safety or the environment are. The regulators therefore consider that the clarity and usability of this report needs to be reviewed in the context of it being a main reference within the safety and environmental cases for UK ABWR, in line with SAP SC.2 [3].

The purpose of this ROA is therefore to ensure that the report(s) produced to define the source terms under Action 1 of this RO are presented in a manner that are appropriate for use in the UK ABWR safety and environmental cases.

REGULATORY EXPECTATIONS

In response to this ROA the regulators expect:

(a) Hitachi-GE to review the expectations given in SAP SC.2, and more generally under the SAP section "*the regulatory assessment of safety cases*", in their responses to Action 1 and identify any deficiencies.

(b) Hitachi-GE to review how their responses to Action 1 will form part of the hierarchy of submissions which collectively will form the UK ABWR safety and environmental cases and

identify any deficiencies.

(c) Hitachi-GE should provide an updated response to Action 1, an accompanying summary report or some other alternate means to address any identified deficiencies in the presentation of their response to Action 1.

GLOSSARY

BAT – Best Available Techniques

BWR –Boiling Water Reactor

CRUD – Chalk River Unidentified Deposit

Expected event – events that are expected to occur over the lifetime of the plant. This does not include events that are inconsistent with the use of BAT such as accidents, inadequate maintenance and inadequate operation.

GEP – Generic Environmental Permit

Operational States – Including "normal operations" and "anticipated operational occurrences". For a nuclear power plant, this includes start-up, power operation, shutting down, shutdown, maintenance, testing and refuelling.

ORE – Operational Radiation Exposure

PCSR – Pre-construction Safety Report

RO – Regulatory Observation

ROA – Regulatory Observation Action

RPV – Reactor Pressure Vessel

Severe accident - As defined in the SAPs. A fault sequence which leads either to consequences exceeding the highest radiological doses given in the BSLs of Target 4, or to a substantial unintended relocation of radioactive material within the facility which places a demand on the integrity of the remaining physical barriers

SFAIRP – So Far as is Reasonably Practicable

Source term – The types, quantities, and physical and chemical forms of the radionuclides present in a nuclear facility that have the potential to give rise to exposure to radiation, radioactive waste or discharges

UK ABWR – UK Advanced Boiling Water Reactor

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