REGULATORY OBSERVATION

REGULATOR TO COMPLETE

RO unique no.:	RO-ABWR-0081
Date sent:	10 May 2017
Acknowledgement required by:	01 June 2017
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.:	2017/183736
Related RQ / RO No. and TRIM Ref. (if any)**:**	RQ-0957 (TRIM: 2016/249676) RQ-0970 (TRIM: 2016/265513) RQ-1038 (TRIM: 2016/337504) RQ-1198 (TRIM: 2016/471006) RQ-1351 (TRIM: 2017/87124) RQ-1352 (TRIM: 2017/87148)
Observation title:	UK ABWR Sampling Capabilities
Technical area(s) 9. Reactor Chemistry	**Related technical area(s)** 4. PSA 5. Fault Studies 6. Control and Istrumentation 10.Radiation Protection & (Level 3 PSA)

Regulatory Observation

SUMMARY

The primary objective of this Regulatory Observation (RO) is to state ONR's expectations with respect to Hitachi-GE producing a robust justification that the UK ABWR sampling systems are adequate to determine all chemistry and radiochemistry parameters necessary in the interests of safety, during normal operations and faults, in a manner that reduces risks So Far As Is Reasonably Practicable (SFAIRP). For the purposes of this RO, use of 'chemistry' is also intended to include consideration of radiochemical parameters. Similarly, 'normal operations' includes start-up, power operation, shutting down, shutdown, maintenance, testing and refuelling.

ONR's assessment of the sampling and monitoring (SAM) system has revealed there is insufficient information presented in Hitachi-GE safety case submissions of the SAM system design itself to allow a meaningful assessment to take place. Further, there is little underpinning evidence provided to support arguments proposed as to the SAM systems ability to provide representative samples. Assessment has also determined post-accident sampling (following a design basis fault) is performed primarily via the SAM system, which is the same system used during normal operations. Clearly, the requirements and safety considerations differ between these two states.

ONR's assessment has identified a number of gaps between Hitachi-GE's submissions and regulatory expectations, with this RO therefore raised to ensure regulatory expectations are clearly understood. Until a suitable level of information and robust demonstration has been provided, which takes account of all relevant risks which the UK ABWR sampling system(s) are required to mitigate; ONR cannot form a judgement on whether the design of the sampling systems ensures the legal duty of controlling and reducing risks to ALARP[1] will be met.

BACKGROUND

The sampling system of a nuclear power station is vital in ensuring that the operator understands, and hence can control, the numerous chemical systems and functions that are required for safe operation of the plant during all modes of reactor operation, including shutdown and accident conditions to enable proper recovery and inform operator actions. For clarity, sampling for normal operations and post-accident are discussed

[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.

separately.

Normal Operations Sampling

During the course of Step 4 assessment, ONR has issued a series of Regulatory Queries (RQ) regarding normal operation sampling and monitoring (Ref. 1, 2 & 3); in addition to discussing expectations with Hitachi-GE during Level 4 meetings (Ref. 6, 8, 9). In these interactions and RQs respectively, ONR has highlighted that the design information presented for the SAM system is generic and at principle level. Additionally, there is little justification provided for the SAM systems ability to provide representative samples,

The main submissions ONR has assessed to date regarding the SAM system have included the Design Justification Report on Primary Water Systems (Ref. 13), of which the SAM is a subsection amongst other topics and not therefore the main focus, the Topic Report on Sampling and Monitoring Philosophy (Ref. 22) and the System Design Description for the SAM (Ref. 14). While Ref. 22 does provide a reasonable set of principles for design of a sampling and monitoring system, this suite of submissions to date have not provided suitable and sufficient information on the design of the SAM to allow ONR to perform a meaningful assessment during GDA. SAM design information presented in Ref. 13 and 14 is similarly at a high level, and while a number of arguments are presented for the extant design, these are not appropriately supported with evidence. ONR therefore considers:

- There is insufficient design information presented in submissions to date regarding the SAM to allow ONR to perform a meaningful assessment
- Arguments presented for the SAM systems' ability to provide safe and representative samples are inadequately evidenced

Post-accident Sampling

ONR previously outlined our expectations for post-accident sampling to Hitachi-GE in a letter sent on 23 February 2016 (Ref. 4). This defined the terminology for post-accident (any time after the initiating event, as opposed to time after the achievement of a safe state, for example) and sampling (any measurement requirement, not constrained to only those which require the physical removal of a sample for analysis) respectively. Additional ONR expectations for the topic were also stated in Ref. 4, including:

1. Hitachi-GE should, as part of their safety submissions, define what the post-accident sampling requirements are for UK ABWR, including "what, where, when and how".
2. For those parameters where there is a safety requirement for sampling to manage or mitigate the accident, either during the accident progression or for longer-term management of consequences, ONR would expect these to be included within the scope of GDA.
3. Consideration should be given to the longer term phases of an accident. While GDA is not concerned with how a future licensee may choose to manage recovery from an accident, it should include consideration of sampling design features that are likely to be required.
4. The level of design detail should be proportionate to the safety significance of the parameter. For all parameters which have safety significance ONR would expect a demonstration of the capability to sample as a minimum, regardless of the detailed design to be employed.

A number of meetings have subsequently been held to discuss post-accident sampling (for example, Ref. 5, 6, 7, 8 & 9), with participation from other ONR disciplines including PSA, C&I and Fault Studies at a number of these, further clarifying ONR expectations.

Hitachi-GE's submissions received to date which cover post-accident monitoring parameters have been divided across References 11 and 12 for design basis and severe accident scenarios, respectively; however submissions covering the design basis topic have been subject to a number of delays. The adequacy of the design of UK ABWR post-accident sampling system(s) used to acquire chemistry parameters for severe accidents are not within the scope of this RO; they are instead the subject of queries raised in Regulatory Query RQ-ABWR-1352 (Ref. 10).

Having now assessed Ref. 11 however, it is now clearly apparent to ONR that the SAM system does indeed perform role(s) in design basis accident(s). Based on our assessment to date of Reference 8 and other Hitachi-GE documentation previously submitted to ONR (Ref. 12 , 13 & 14) , ONR does not consider that Hitachi-GE has provided an adequate justification to demonstrate that the sampling of chemistry parameters necessary in the interests of safety, in a design basis accident for UK ABWR, reduces risks SFAIRP. Furthermore, the submissions to date are deficient in two important aspects:

- They are vague in terms of what parameters will be measured and when; and
- They do not provide any justification regarding the adequacy of the SAM to safely perform the identified sampling.

REGULATORY EXPECTATIONS

RGP and comparison with UK ABWR

The selected operating chemistry is novel to the UK ABWR design. ONR is therefore primarily seeking confidence that the design and operation of the SAM system is sufficient to support safe operations in line with the safety case, as expected by SAP ECH.4 (Ref. 21) as follows:

Engineering principles: chemistry	Monitoring, sampling and analysis	ECH.4
Suitable and sufficient systems, processes and procedures should be provided for monitoring, sampling and analysis so that all chemistry parameters important to safety are properly controlled.		

518. Guidance on assessing the characterisation of nuclear matter and radioactive waste may also be relevant here (see Principles ENM.5 and RW.4). The chemistry monitoring, sampling and analysis should:

(a) verify the effectiveness of chemistry control in systems and that structures, systems and components are being operated within specified limits (operating rules). Consideration should be given to providing alarms to assist the chemistry monitoring regime;

(b) be performed according to a clearly defined scope and periodicity;

(c) be applied under appropriate conditions defined to ensure representative sampling is undertaken;

(d) adopt an appropriate balance between on-plant measurements and laboratory analysis; and

(e) utilise appropriate processes and procedures.

TAG-88 (Ref. 23) provides further information on ECH.4, while ONR would also considers ENM.1 to ENM.7 apply for the sampling, characterisation and control of nuclear matter. Specifically for ECH.4, the overarching requirement is for sampling systems to allow representative samples to be obtained for proper control of chemistry parameters important to safety. While ONR appreciates that the design of the sampling system for GDA is subject to change during detailed design, ONR requires confidence during GDA that the design of sampling systems is sufficient to enable this. Therefore, while not exhaustive, the following key points should be considered:

- Sample point locations, including the impact of temperature on solubility of key species with careful consideration of the location of cooling equipment
- Sample line length, diameters and flow rates
- Consideration within the safety case of the impact of failure to collect accurate samples
- Impact of sampling on waste generation

The requirement to for process and post-accident sampling capability is explicitly captured within requirement 71 of SSR-2.1 (Ref. 15), which states: *"Process sampling systems and post-accident sampling systems shall be provided for determining, in a timely manner, the concentration of specified radionuclides in fluid process systems, and in gas and liquid samples taken from systems or from the environment, in all operational states and in accident conditions at the nuclear power plant."* SSG-13 (Ref. 16) provides expectations for sampling systems for normal operations and post-accident conditions in sections 6.41 to 6.44. For normal sampling systems, the following extracts apply for GDA: "*Appropriate consideration should be given to the need for correct sampling conditions… Representative grab samples should be ensured by appropriate flushing of sampling lines, proper determination of the flow rate..*" Similarly, SSG-13 highlights *"A post-accident sampling system or other adequate sampling facility should be ready to operate when required by emergency*

procedures and should also be considered for use in taking regular samples from plant systems." SSG-13 further details that a number of provisions should be made to support the operation of a post-accident sampling system. Of these, ONR considers the following to be applicable for consideration in GDA:

> *(b) Radiation protection measures for personnel who carry out sampling and analysis; such measures should be evaluated in advance and applied when the post-accident sampling system is used.*
> *(d) Regular checks of the operability of the post-accident sampling system.*
> *(f) Specification of the chemistry parameters to be monitored (e.g. conductivity in the reactor water cleanup system and gaseous fission products in the main steam system).*

With the exception of SSR 2-1, Ref. 13, 14 and 22 do not appear to consider any of the above international or ONR standards and guidance in the design of the SAM system for use in normal operations. More importantly, there is no consideration of OPEX from worldwide reactors which implement a similar chemistry regime to that of UK ABWR. With respect to post-accident sampling, Ref. 11 currently utilises United States Nuclear Regulatory Commission (US NRC) guidance (Ref. 17) as the main source of comparison for parameters to be monitored in a design basis accident, supplemented by identification of monitoring variables from an Institute of Electrical and Electronics Engineers (IEEE) standard (Ref. 18). Given these documents have both been superseded and are over 23 and 14 years old, respectively, ONR would question why more modern guidance has not been considered along with other relevant guidance from the International Atomic Energy Agency (IAEA) (Ref. 15 and 16) and Western European Nuclear Regulators Association (WENRA) (Ref. 19). Most importantly, ONR would expect experience from other operating BWR post-accident sampling and monitoring arrangements to be considered and compared with UK ABWR.

Normal Operations Sampling

1. ***Presentation of suitable and sufficient information of the specific UK ABWR SAM system design***

ONR requires sufficient information of the SAM design to allow a meaningful assessment. While Ref. 22 provides a reasonable set of principles for the SAM system, from the suite of documentation currently available to ONR it is not clear what the specific design of the UK ABWR system entails. This should include consideration of relevant ONR, IAEA and WENRA guidance described above. In particular, SAP ECH. 4 is applicable (Ref. 21), along with additional guidance in ONR TAGs (Ref. 23). This should also include presentation of a sampling schedule specific to UK ABWR.

2. ***Justification that the UK ABWR sampling and monitoring design is adequate to support normal operations***

Key to demonstrating that the SAM system within UK ABWR is capable of providing timely and representative sampling of chemistry parameters to support safe normal operations, Hitachi-GE should provide evidence and justification. While Ref. 13 presents some arguments for representative sampling in UK ABWR, this is not appropriately underpinned. This should consider specific design features of the UK ABWR and consideration of worldwide BWRs of a similar operating chemistry.

Post-accident Sampling

1. ***Identification and justification of parameters to be monitored***

ONR expects all parameters where there is a safety requirement for sampling to manage or mitigate the accident to be appropriately identified and justified. In doing so, ONR would expect consideration of relevant ONR, IAEA and WENRA guidance highlighted above to be considered. Specifically, Ref. 16 recommends provision of the "*specification of the chemistry parameters to be monitored (e.g.) conductivity in the reactor water clean-up system and gaseous fission products in the main steam system)*". ONR TAGs (Ref. 20) and SAPs (Ref. 21) also apply, in particular ECH.1 (identification of all parameters) and ECH.4 (monitoring, sampling and analysis).

2. ***Demonstration the SAM is capable of fulfilling its safety function in a Design Basis Accident***

While Ref. 8 indicates that sampling of reactor water is required in a design basis event, no Hitachi-GE submissions received and assessed by ONR to date, provide an adequate justification that the SAM system design is capable of delivering the function(s) required to monitor these, or other chemistry related parameters in a design basis accident. Specifically, such justification is absent from Ref. 13, while Ref. 14 is limited to stating that "*The SAM piping and component are designed for a useful operating life of 60 years including a 100 days of continuous post-accident operation*.".

References:

1. RQ-ABWR-1038 – Chemistry Monitoring & Sampling Queries – 25th August 2016
2. RQ-ABWR-1198 – Chemistry Monitoring & Sampling Queries 2 – 2nd December 2016
3. RQ-ABWR-1351 – Chemistry Monitoring & Sampling Queries 3 – 2nd March 2017
4. Scope of Post-Accident Sampling for the Reactor Chemistry Assessment of GDA for UK ABWR Letter, REG-HGNE-0127R, 23rd February 2016
5. ONR-GDA-CR-15-458 – Reactor Chemistry Progress Meetings – 1st to 7th March 2016
6. ONR-NR-CR-16-180 – PAS Cross-cutting Meeting – 16th May 2016
7. ONR-NR-CR-16-320 – Level 4 Fault Studies and Severe Accident Progress Meeting – 20th to 24th June 2016
8. ONR-NR-CR-16-557 – UK ABWR Reactor Chemistry Progress and Structural Integrity Meetings – 12th 13th and 16th September 2016
9. ONR-NR-CR-16-993 – UK ABWR Reactor Chemistry Progress Level 4 Meeting – 17th February 2017
10. RQ-ABWR-1352 – Accident Sampling & Monitoring – 2nd March 2017
11. Monitoring Parameter in DBF, UE-GD-0602R0 Rev. 0 – 28th February 2017
12. Monitoring Parameters for Severe Accident Management in UK ABWR, AE-GD-0774 Rev. 0 – 7th September 2016
13. Topic Report on Design Justification in Chemistry Aspect for Primary Water Systems, WPE-GD-0232 Rev. 1 – 31st August 2016
14. System Design Description for Sampling System, SD-GD-0024 Rev. 1 – 13th September 2016
15. Safety of Nuclear Power Plants: Design, IAEA Guide SSR-2.1 – 2016
16. Chemistry Programme for Water Cooled Nuclear Power Plants, IAEA Guide SSG-13 – 2011
17. Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident, NRC Regulatory Guide 1.97 Rev. 3 – May 1983
18. IEEE Power Engineering Society, IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations, IEEE Std. 497-2002
19. *Western European Nuclear Regulators' Association. Reactor Harmonization Group. WENRA Reactor Reference Safety Levels for Existing Reactors, WENRA. September 2014.*
20. The limits and conditions for nuclear plant safety. NS-TAST-GD-035 Issue 4. August 2014. www.onr.org.uk/operational/tech_asst_guides/index.htm
21. Safety Assessment Principles for Nuclear Facilities 2014 Edition Revision 0. November 2014. www.onr.org.uk/saps/saps2014.pdf.
22. Topic Report on Sampling and Monitoring Philosophy for Chemical and Radiochemical Parameters, WPE-GD-0358 Rev.0 – 30th March 2017
23. Chemistry of Operating Civil Nuclear Reactors. NS-TAST-GD-088 Issue 1. April 2017. www.onr.org.uk/operational/tech_asst_guides/index.htm

Regulatory Observation Actions

RO-ABWR-0081.A1– Presentation of suitable and sufficient information to enable a meaningful assessment of the sampling and monitoring systems

Hitachi-GE should provide suitable and sufficient design information for the UK ABWR specific sampling and monitoring system in order to allow ONR to perform a meaningful assessment. Specifically, this should include:

1. A sample schedule required to support operation of UK ABWR, This schedule should include consideration of all modes of operation and should consider:
    - Which type of sampling line applies for the most significant chemistry parameters to nuclear safety
    - Parameters to be measured from which location and the frequency of sampling

- The schedule should be clearly linked back to the safety case
- Where the sample is expected to be collected
- Primary circuit and auxiliaries, including but not limited to the Spent Fuel Pool and Liquid Waste Management System (LWMS)

The details should be specific to the UK ABWR plant and any differences in plant design; reference to industry guidelines is not a sufficient response in itself.

2. Design information of the sampling and monitoring system, for all types of sampling lines (i.e. continuous, continuous recycle and grab sample). This should include:
   - Diagrammatical presentation of sampling lines. While this need not be detailed 3D piping images, these should be sufficiently detailed and include: Sample line length/diameter, containment penetrations, cooling measures (and source), pressure reduction measures, isolation valves, flushing measures, sumps, sample hoods, sample sinks, sample filter racks and online meters.
   - A description of how the UK ABWR sampling and monitoring system will work in practice. While this should not include detailed descriptions of sampling procedures, this should be at an appropriate level to allow an appreciation of sampling system operation.

3. Identification of any changes to the reference design in light of chemistry changes for UK ABWR

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-0081.A2 – Justification that the UK ABWR sampling and monitoring design is adequate to support normal operations

Hitachi-GE should provide an appropriate justification that the sampling and monitoring system design described under A1 of this RO is capable of providing timely and representative sampling to support safe normal operations. Specifically, the response should consider:

- Specific features of the UK ABWR design, such as the location of cooling provisions and the maintenance of high pressure lines.
- Consideration of the effect of any design changes (material and chemical) to the sampling system
- Consideration of operator safety (both radiological and conventional) in collection and transport of samples
- The approach to recycle all sample effluent in the reactor, with specific consideration on generation of secondary waste

Importantly, in justifying the design of the sampling and monitoring design system, Hitachi-GE should provide a comparison with sampling system designs of worldwide BWRs which operate with a chemistry regime to that proposed for UK ABWR. Additionally, this should be supplemented by evidence (for example, OPEX) to substantiate representivity of the UK ABWR sampling and monitoring system,

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-0081.A3 – Definition and justification for chemistry-related parameters required in design basis post-accident sampling

In line with ONR's SAPs, TAGs and IAEA guidance, Hitachi-GE should identify and justify all chemistry parameters required to be monitored during or following a design basis event. Specifically, this should include:

- Identification of what chemistry related parameters will be measured in a design basis accident.
- Description of when measurement of identified chemistry parameters is necessary, i.e. both temporally and for which fault sequences
- Suitable justification of identified chemistry related parameters, with consideration of design basis accident sampling within other worldwide BWRs

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-0081.A4 – Demonstration that the UK ABWR design is adequate to support post-accident sampling

Based on the response to Action 3, Hitachi-GE should provide a demonstration that the means by which monitoring will be delivered are sufficient. Specifically, this should include:

- Representivity of post accident sampling and monitoring
- Operator safety in terms of safe collection, handling and return of samples
- Comparison of the UK ABWR to identified RGP and other BWR designs
- Categorisation and classification of SSCs required to deliver design basis accident sampling

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:	