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.:	2016/322866
Related RQ / RO No. and TRIM Ref. (if any)**:**	N/A
Observation title:	Suitable and sufficient consideration of chemistry control during UK ABWR commissioning
Technical area(s) 9. Reactor Chemistry	**Related technical area(s)** 10. Radiation Protection & (Level 3 PSA)

Regulatory Observation

The objective of this Regulatory Observation (RO) is to state ONR's expectations with respect to Hitachi-GE giving suitable and sufficient consideration of chemistry control during UK ABWR commissioning, as part of Generic Design Assessment (GDA).

The chemistry adopted during commissioning of a nuclear reactor is generally accepted to be one of several key factors which has important consequences for the longer-term behaviour of the plant; notably on the build-up and release of radioactivity and the plant's susceptibility to materials degradation threats. Many nuclear power plants therefore pay close attention to chemistry control implemented during this phase of reactor operations, in order to achieve low plant dose rates during the operating life of the facility.

Hitachi-GE have produced and submitted to ONR for formal assessment, safety case submissions to demonstrate the approach to chemistry control during commissioning for UK ABWR, reduces relevant risks to As Low As Reasonably Practicable (ALARP). ONR's assessment of these documents is now complete. ONR has identified some specific reservations with the application of Hitachi-GE's methodology to justify chemistry control during commissioning for UK ABWR will reduce risks to ALARP, as Hitachi-GE claim.

Hitachi-GE's conclusion on what constitutes the 'ALARP option' for 'commissioning chemistry' *may* be reasonable, however, ONR's view is that the focus of, and approach to the current ALARP demonstration, needs to be given further consideration by Hitachi-GE, before ONR can judge whether this position is justified and a robust position has been reached for GDA.

ONR has therefore judged that so far, for GDA, Hitachi-GE has not given suitable and sufficient consideration to chemistry control during UK ABWR commissioning. This RO has therefore been raised to make regulatory expectations clear and to explicitly highlight, in ONR's view, what is within the scope of this topic for GDA.

BACKGROUND

Introduction and UK Experience

The chemistry adopted during commissioning of a nuclear reactor is generally accepted to be one of several key factors which have important consequences for the longer-term behaviour of the plant. This is especially true for Structures, Systems and Components (SSCs) of the reactor which are in direct contact with the 'primary' coolant and how in subsequent fuel cycles, and perhaps over the entire lifetime of the plant, they behave, with respect to the build-up and release of radioactivity and their susceptibility to materials degradation threats. Many nuclear power plants therefore pay close attention to chemistry control implemented during this phase of reactor operations, in order to achieve low plant dose rates during the operating life of the facility.

The last nuclear power plant to be commissioned in the United Kingdom (UK) was Sizewell 'B' (SZB) in 1994-1995. Although SZB is a Pressurised Water Reactor (PWR), the aims and objectives for chemistry control during commissioning of a PWR or a Boiling Water Reactor (BWR), should be broadly the same, namely to:

1. Minimise longer-term Operational Radiation Exposure (ORE);
2. Minimise the risk of materials degradation threats to SSCs.

To commission SZB, therefore, the decision was taken to implement a 'different' chemistry during Hot Functional Testing (HFT), rendering SZB, at that time, first of a kind. HFT is a term often used for PWR plants to describe one of (the) first period(s) of reactor operations under full temperature and pressure conditions (without nuclear fuel being present in the core). The HFT chemistry applied at SZB was aimed at forming a good passive film under the correct redox conditions (*i.e.* as compared to the 'at power' operating chemistry for the primary circuit, with hydrogen present) and to remove as many corrosion products as possible before power operation.

Following implementation of this HFT chemistry, shutdown releases of radioactivity at SZB in subsequent fuel cycles were very low, consistent with the absence of fuel CRUD on fuel clad surfaces. It is believed the main benefit of the HFT chemistry applied may have been to accelerate the formation of a passive oxide layer on Steam Generator (SG) tubing. The impact of the HFT chemistry applied at SZB, amongst other factors, has been so pronounced, that it is currently judged as not being necessary to inject zinc into the primary circuit to minimise shutdown dose rates [1].

The approach to chemistry control early in the operating life of the reactor for other PWR plants has been similarly carefully considered, with recent experience focussed on zinc injection. Two particular examples include the Angra-2 plant in Brazil, which began zinc injection a few days after first criticality, and the Tomari-3 plant in Japan. Tomari-3 was the first plant in the world to inject zinc for the purposes of dose rate reduction, starting from HFT [2]. Evidence emerging from both plants is encouraging; with dose rates being reported as significantly lower than comparable plants which do not inject zinc during these periods of operation.

Current Approach for UK ABWR

For UK ABWR, Hitachi-GE has decided the 'at power' operating chemistry will be to implement Hydrogen Water Chemistry (HWC), Depleted Zinc Oxide (DZO) injection and On-line Noble Metal Chemistry (OLNC). Hitachi-GE has produced a demonstration to justify this choice of operating chemistry, on balance, reduces relevant risks to As Low as Reasonably Practicable (ALARP) [3].

In addition, in preparing the reactor chemistry aspects of the UK ABWR safety case for GDA, Hitachi-GE has also considered chemistry control during other phases of operation including: commissioning, start-up and shutdown and the approach to iron control, also to justify chemistry control during these phases reduces relevant risks to ALARP. The totality of the 'ALARP demonstrations' for these phases of operation are reported in two primary documents:

1. *"Topic Report on the Water Chemistry Regime ALARP Assessments on the Iron Control at Power, Commissioning, Start-up and Shutdown Operational Modes: Part 1 – Main justification* [4], and;
2. *"Topic Report on the Water Chemistry Regime ALARP Assessments on the Iron Control at Power, Commissioning, Start-up and Shutdown Operational Modes: Part 2 – ALARP Workshop Method and Record* [5].

These Topic Reports are also supported by several more detailed 'evidence documents'. ONR has undertaken an assessment of References 4 and 5 and for the commissioning phase of operations, Hitachi-GE's Topic Report on Commissioning Chemistry [6].

Following our assessment, ONR has concluded that overall, Hitachi-GE has developed an adequate methodology to produce ALARP justifications for chemistry control during these phases of reactor operations. Despite this, however, ONR has identified some specific reservations with the application of this methodology to justify chemistry control during commissioning for UK ABWR will reduce risks to ALARP. ONR's main observations with Hitachi-GE's current approach are:

- The aims and objectives for chemistry control during UK ABWR commissioning are not clearly stated;
- As presented, the ALARP demonstration appears to focus very heavily on the need to mitigate Stress

Corrosion Cracking (SCC) and risks to the structural integrity of the plant, as opposed to minimising long-term Operational Radiation Exposure;
- It is not clear which parts of the plant are, and need to be targeted, to claim risks will be reduced to ALARP by the choice of chemistry control during commissioning;
- Little evidence is presented to support some of the key arguments invoked to dismiss the application of alternative options.

Hitachi-GE's overall conclusion, therefore, is that based on past practices for commissioning BWRs, the 'ALARP option' for chemistry control during UK ABWR commissioning is essentially to use deaerated, demineralised water with minimised impurities. This *may* be a reasonable conclusion, however, ONR's view is that the focus of, and approach to the current ALARP demonstration, needs to be given further consideration by Hitachi-GE, before ONR can judge whether this position is justified and a robust position has been reached for GDA.

Amongst other factors, ONR's conclusion is supported by the UK experience of commissioning SZB, where departure from 'routine' *i.e.* past practices (at the time), in chemistry control during HFT, was a key factor in the plant achieving significant longer-term nuclear safety benefits in terms of its behaviour with respect to the generation and transport of radioactivity. This approach to HFT chemistry control is now widely adopted by almost all new PWR plants entering commissioning.

Although there may be some key differences between commissioning PWR and BWR plants and perhaps therefore, some constraints, in what can reasonably be achieved for UK ABWR, the chemistry aims and objectives and principles should be broadly the same. Taking this, and the approach adopted at SZB into account, ONR's view, therefore, is that it is not clear whether past practices for commissioning BWRs are directly applicable to UK ABWR, given the decision to adopt HWC, DZO and OLNC very early in the life of the plant. In addition, ONR considers Hitachi-GE's current approach may foreclose reasonably practicable options too early and in doing so, may not deal with the management of uncertainties in an appropriate way.

ONR has therefore judged that so far, for GDA, Hitachi-GE has not given suitable and sufficient consideration to chemistry control during UK ABWR commissioning. This RO has therefore been raised to make regulatory expectations clear and to explicitly highlight, in ONR's view, what is within the scope of this topic for GDA.

REGULATORY EXPECTATIONS

Under UK legislation, a fundamental part of demonstrating compliance with the Ionising Radiations Regulations (IRRs) [7], are strategies to restrict radiation exposure, including minimisation of sources of radiation. Adequate control of chemistry during the commissioning phase of a nuclear power plant can therefore be part of the strategy to minimise dose, by minimising out-of-core radiation fields.

ONR therefore expect Hitachi-GE to take cognisance of relevant standards and guidance, including ONR's Safety Assessment Principles (SAPs) [8] and Technical Assessment Guides (TAGs) [9]. For the SAPs, ONR would expect Hitachi-GE to consider the requirements of the chemistry SAPs, in particular ECH.1.

ONR also expect Hitachi-GE to consider the guidance provided in NS-TAST-GD-088, *Chemistry of Operating Civil Nuclear Reactors* [10]. In addition, 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 'commissioning chemistry' for UK ABWR.

As already stated in the Background section to this RO, ONR does not expect Hitachi-GE to make any significant amendments to their methodology for producing the ALARP demonstration for 'commissioning chemistry', rather, the requirement(s) for this RO are for Hitachi-GE to re-consider the focus and assumptions determined as inputs to their ALARP methodology.

It is important to stress that for GDA, it is not reasonable to expect Hitachi-GE to have a fully developed set of commissioning arrangements, methods and procedures, including details of chemistry specific requirements. This is because there are decisions for a prospective Licensee/operator to take about how any UK ABWR unit may be commissioned in the future, but also because international experience and further research and development work, could reasonably be expected to influence the final decision.

Nevertheless, given the important contribution ‘commissioning chemistry’ would be expected to make to the long-term behaviour of any UK ABWR, regardless of operator specific considerations and preferences, ONR expect Hitachi-GE to provide adequate information to demonstrate the focus of the ‘commissioning chemistry ‘ ALARP demonstration provided in GDA is proportionate and appropriate *i.e.* <u>there is a robust justification that the *expected* UK ABWR commissioning procedures will reduce relevant risks SFAIRP.</u> Only after GDA, do ONR expect to see a fully developed commissioning procedure for UK ABWR, including adequate consideration of chemistry; building upon the evidence presented during GDA, but including further relevant knowledge and understanding from various sources, as developments in this area continue.

For clarity, during GDA, ONR therefore expect Hitachi-GE to provide the following information to demonstrate suitable and sufficient consideration has been given to chemistry during UK ABWR commissioning:

- Identify the main, most recent, relevant good practices and approaches in chemistry implemented for commissioning Boiling Water Reactor (BWR) plants similar to, or the same as UK ABWR;
- Identify the specific aims and objectives for chemistry control during UK ABWR commissioning;
- Identify the main fundamental chemistry processes and/or steps *expected* to be involved in UK ABWR commissioning, with specific emphasis on meeting the objectives identified above, rather than what may be achieved with the current design or arrangements;
- Identify any constraints on other matters relating to commissioning activities, which may influence the chemistry choices (e.g. achievable temperatures or durations);
- Demonstration of the availability and capability of UK ABWR systems to support the above, main fundamental UK ABWR *expected* chemistry processes/procedures;
- Consideration of any alternative methods to implement chemistry control during commissioning operations *i.e.* higher concentrations, increased durations;
- Consideration of any necessary, reasonably practicable improvements to UK ABWR systems to deliver complementary chemistry procedures *i.e*. purification, sampling, injection during commissioning;
- Identify chemistry parameters/procedures/approaches which are suitable for a prospective UK ABWR operator to give further consideration to;
- Identify areas where further development work/evidence/plant experience is required to underpin future decisions on chemistry control during UK ABWR commissioning.

For the purpose of this RO, ONR define the scope of commissioning chemistry to include the period from first operations until the time at which the normal at-power operating chemistry of HWC/OLNC and DZO has been established and start-up and shutdown procedures follow the expected practices for the plant. This may therefore extend someway into, or the whole of, the first cycle with nuclear fuel depending on the choices made.

Based on the expectations given above, ONR therefore considers it may not be reasonable to expect the output of the consideration of chemistry control during commissioning for UK ABWR, for GDA, to culminate in a definitive conclusion and ‘agreed’ set of chemistry parameters, concentrations and timings *etc*. to be applied during UK ABWR commissioning.

ONR recognises the importance of not foreclosing options at this stage and of considering current state-of-the art to demonstrate and justify the future approach to UK ABWR ‘commissioning chemistry’ reduces risks to ALARP. Nevertheless, for GDA, ONR does expect there to be a demonstration that the generic design is capable of supporting option(s) which a future Licensee/operator may choose to adopt to achieve adequate chemistry control during UK ABWR commissioning, to claim risks will be reduced to ALARP.

References:

[1] Nuclear Installations Inspectorate, *Primary Chemistry Course*, K. Garbett, 2010.
[2] Nuclear Plant Chemistry Conference 2014, Sapporo, *The Effects of Zinc Injection from HFT at Tomari Unit 3,* Y. Aizawa *et. al,* October 2014.
[3] UK ABWR GDA, *Reactor Chemistry Safety Case: Demonstration that the Primary Cooling System Operating Chemistry Reduces Risks SFAIRP*, Revision 1, Hitachi-GE, June 2015. TRIM 2015/241393.
[4] UK ABWR GDA, *Topic Report on the Water Chemistry Regime ALARP Assessments on the Iron Control at Power, Commissioning, Start-up and Shutdown Operational Modes: Part 1 – Main justification,* Revision 0, Hitachi-GE, April 2016. TRIM 2016/189178.

[5] UK ABWR GDA, *Topic Report on the Water Chemistry Regime ALARP Assessments on the Iron Control at Power, Commissioning, Start-up and Shutdown Operational Modes: Part 2 – ALARP Workshop Method and Record* Revision 0, Hitachi-GE, April 2016. TRIM 2016/189186.
[6] UK ABWR GDA, *Topic Report on Commissioning Chemistry*, Revision 0, Hitachi-GE, April 2016. TRIM 2016/178037.
[7] Nuclear Safety Technical Inspection Guide, *The Ionising Radiations Regulations*, Nuclear Safety Technical Inspection Guide, Revision 4, ONR, November 2014.
http://www.onr.org.uk/operational/tech_insp_guides/ns-insp-gd-054.pdf
[8] Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0, ONR.
http://www.onr.org.uk/saps/
[9] Technical Assessment Guides, ONR. http://www.onr.org.uk/tagsrevision.htm
[10] Technical Assessment Guides, *Chemistry of Operating Civil Nuclear Reactors*, Revision 0, ONR, April 2014. http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-088.pdf
[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-0072.A1 – Hitachi-GE are required to provide an evaluation of current, relevant good practice, in the field of BWR commissioning

In response to this Action, Hitachi-GE should seek to identify and describe Relevant Good Practice (RGP) in the field of BWR commissioning. The response should consider any good practices identified in engineering, operations and/or management of safety. The response should include both general commissioning activities (i.e. timings and/or durations of engineering activities) and chemistry controls.

One important source of RGP is what is done on similar facilities. The evaluation should therefore take due account of the 'at power' operating chemistry of HWC, DZO and OLNC planned to be implemented from the start of life for UK ABWR, and be clear, therefore, whether more recent, past practices in BWR commissioning remain relevant. The response should be clear on the applicability of the good practice or standard identified, to 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-0072.A2 – Hitachi-GE are required to provide a description of the specific aims and objectives for chemistry control during UK ABWR commissioning

In response to this Action, Hitachi-GE should seek to clearly state what the principal aims and objectives for chemistry control during UK ABWR commissioning are. The response should focus on UK ABWR Structures, Systems and Components (SSCs) (i.e. impact on the feedwater system, reactor pressure vessel internals, reactor water clean-up system etc.) and phenomena (i.e. generation of radioactivity, integrity of components etc.) most significant to nuclear safety.

The response should clearly identify which UK ABWR SSCs chemistry control during commissioning is specifically targeting and the reason(s) why. The response should also identify and describe the main fundamental chemistry processes/steps expected to be performed during UK ABWR commissioning. ONR would also expect Hitachi-GE to identify chemistry parameters/procedures/approaches which are suitable for a prospective UK ABWR operator to give further consideration to, and provide an adequate justification for why this is appropriate.

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-0072.A3 – Hitachi-GE are required to provide a robust demonstration to justify the expected UK ABWR commissioning procedure(s) is capable of reducing risks SFAIRP, based on the responses to Actions 1 and 2

Based upon the responses provided to Actions 1 and 2, Hitachi-GE should provide a demonstration that the expected approach to chemistry control during UK ABWR commissioning is capable of reducing risks SFAIRP.

The response to this Action should be clearly linked to the aims and objectives (and therefore risks) identified under Action 2.

ONR would expect the response to this Action to:
- *Consider the capability and availability (i.e. the current design) of UK ABWR systems to deliver chemistry control;*
- *Consider alternative methods (options) to implement chemistry control i.e. higher concentrations, increased durations;*
- *Consider any reasonably practicable improvements/modifications to the capability and availability (i.e. the current design) of UK ABWR systems to deliver chemistry control;*
- *Present suitable and sufficient evidence i.e. OPEX, plant experience etc., to support the arguments presented, especially where claims of gross disproportion are invoked;*
- *Deal with areas of uncertainty in an appropriate manner i.e. identify where further development work/evidence/plant experience is required to underpin future decision(s).*

ONR would not expect the response to this Action to fully define what the 'commissioning chemistry' is for any UK ABWR. Instead it may contain, for example, the option or options currently considered most reasonable by Hitachi-GE, plus a demonstration that other potentially beneficial options have not been forclosed and an identification of those areas where further consideration may need to be given by a future Licensee.

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:	