

<b>REGULATORY OBSERVATION</b>	
<b>REGULATOR TO COMPLETE</b>	
<b>RO unique no.:</b>	RO-ABWR-0035
<b>Date sent:</b>	3rd October 2016
<b>Acknowledgement required by:</b>	24th October 2016
<b>Agreement of Resolution Plan Required by:</b>	<i>To be determined by the Hitachi-GE resolution plan</i>
<b>Resolution of Regulatory Observation required by:</b>	<i>To be determined by the Hitachi-GE resolution plan</i>
<b>TRIM Ref.:</b>	2016/382783
<b>Related RQ / RO No. and TRIM Ref. (if any):</b>	RO-ABWR-0006 TRIM 2014/156113 RQ-ABWR-0103 TRIM 2014/142770 RO-ABWR-0034 TRIM 2014/460897
<b>Observation title:</b>	Robust Justification for the Materials selected for UK ABWR
<b>Technical area(s)</b> 9. Reactor Chemistry 12. Structural Integrity	<b>Related technical area(s)</b> 10. Radiation Protection & (Level 3 PSA)
<b>Regulatory Observation</b>	
<b>SUMMARY</b>	
<p>The choice of materials for a particular Structure, System or Component (SSC) of a nuclear reactor is influenced by many competing factors. Therefore, the justification of the most appropriate material selected for a particular SSC requires a balance to be struck. In reaching that balance, there should be a robust demonstration that all of the relevant risks have been considered and reduced So Far as is Reasonably Practicable (SFAIRP).</p> <p>During the Generic Design Assessment (GDA) of the United Kingdom Advanced Boiling Water Reactor (UK ABWR), to date, Hitachi-GE have provided some information related to material choices for the design. The submissions received have been relatively high-level principles, best described as design philosophy documentation [1].</p> <p>As Step 3 of GDA progresses Hitachi-GE plan to make a number of further, more detailed, submissions for particular SSCs, specifically to develop the structural integrity aspects of the safety case for UK ABWR. This approach means the justification of materials selected for UK ABWR is focused on those SSCs where the consequences of failure are greatest. Wider consideration and justification of the materials selected for other SSCs, whose integrity claims may be lower, but the SSC still makes an important contribution to nuclear safety is, however, still necessary to meet ONR's expectations.</p> <p>This Regulatory Observation (RO) is therefore raised to make clear ONR's expectations regarding Hitachi-GE's justification of the materials selected for UK ABWR.</p>	
<b>BACKGROUND</b>	
<p>The choice of materials for a particular SSC of a nuclear reactor is influenced by many competing factors, including:</p> <ul style="list-style-type: none"> <li>• the functional requirements of the SSC;</li> <li>• the tolerance/degradation of the SSC in its operating 'environment', and/or:</li> <li>• the potential hazards and risks, which must be either eliminated, reduced or controlled.</li> </ul> <p>Considering the above factors, and potentially others, it is clear the justification of the most appropriate material selected for a particular SSC requires a balance to be struck. In reaching that balance, there should</p>	

be a robust demonstration that all of the relevant risks have been considered and reduced SFAIRP.

During the Generic Design Assessment (GDA) of the United Kingdom Advanced Boiling Water Reactor (UK ABWR), to date, Hitachi-GE have provided some information related to material choices for the design. The submissions received have been relatively high-level principles, best described as design philosophy documentation.

As Step 3 of GDA progresses Hitachi-GE plan to make a number of further, more detailed, submissions for particular SSCs, specifically to develop the structural integrity aspects of the safety case for UK ABWR.

Hitachi-GE's plan is that these submissions will focus on those SSCs with the highest level of integrity claims. This approach means the justification of materials selected for UK ABWR is focused on those SSCs where the consequences of failure are greatest. Wider consideration and justification of the materials selected for other SSCs, whose integrity claims may be lower, but the SSC still makes an important contribution to nuclear safety is, however, still necessary to meet ONR's expectations.

Hitachi-GE's current approach does not take full consideration of either:

- i. the need to adequately justify materials selected for components below Very High Integrity (VHI);
- ii. the need to balance the requirements of structural integrity, reactor chemistry and radiation protection. To be able to show that, on balance, the relevant risks have been reduced SFAIRP, the requirements of these, and potentially other disciplines; need to be factored in to the justification for the materials selected for UK ABWR.

This RO is therefore raised to make clear ONR's expectations regarding Hitachi-GE's justification of the materials selected for UK ABWR.

### **REGULATORY EXPECTATIONS**

This RO has been raised jointly by the reactor chemistry and structural integrity topics. ONR's expectations in both of these disciplines for Hitachi-GE's justification are aligned, in that ONR expects:

- Hitachi-GE to make materials selection and safety justifications for all UK ABWR SSCs that are proportionate to the significance of identified SSCs in maintaining nuclear safety;
- in doing so, Hitachi-GE to consider the nature, severity and likelihood of materials degradation in UK ABWR;
- Hitachi-GE to make a robust demonstration, showing that risks relating to materials degradation for UK ABWR are reduced SFAIRP.

When considering the above, ONR would expect Hitachi-GE to show:

- all of the relevant risks related to the 'degradation' and through-life integrity of the SSC in question have been considered, for example:
  - a. loss of integrity;
  - b. loss of performance;
  - c. the generation and transport of radioactivity;
- whether other options to eliminate, reduce, or mitigate those risks have been considered;
- to identify and document those options;
- to provide robust evidence of the criteria used in decision making and option selection, and;
- to provide evidence of gross disproportion in terms of cost (time, trouble or money) for options not selected.

Based on the above, ONR's assessment of the response(s) to this RO will be undertaken jointly by reactor chemistry, structural integrity, and radiation protection, as a minimum. ONR therefore expects a similar, coordinated approach, to be adopted by Hitachi-GE.

When forming a judgement on the adequacy of the response to this RO, ONR's principal source of standards and guidance will be the Safety Assessment Principles (SAPs) [2], in some cases supplemented by the

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relevant Technical Assessment Guide (TAG). Although ONR's expectations for materials selection for UK ABWR are aligned between topics, ultimately the assessment in each area will be approached from slightly different perspectives.

For structural integrity, two of the engineering principles on ageing and degradation, EAD.1 and EAD.2, are particularly pertinent:

- EAD.1 requires the safe working life of SSCs that are important to safety to be evaluated and defined at the design stage;
- EAD.2 sets the requirement for adequate margins to exist throughout the life of a facility to allow for the effects of materials ageing and degradation processes on SSCs important to safety.

To provide confidence these SAPs have been adequately addressed, ONR would therefore expect Hitachi-GE to adopt a graded approach, where the level of information provided relates to the safety significance of the SSC. This means ONR expects SSCs ranging from Class 3 to VHI Components to be considered, but would expect the depth of their consideration to be different.

Further guidance is available in ONR's TAG, *Integrity of Metal Components and Structures* [3].

Reactor chemistry also plays a part in demonstrating the above SAPs, and others related to structural integrity, are satisfied. Further guidance on the impact of reactor chemistry influence on material integrity is provided in the relevant TAG, *Chemistry of Operating Civil Nuclear Reactors* [4].

The justification of the material choices for UK ABWR, from the perspective of demonstrating that radioactivity generation and transport has been reduced SFAIRP, is the subject of a Regulatory Observation Action (ROA) attached to a different RO on source terms, RO-ABWR-0006 [5]. There is a link between that particular ROA (ROA4) of RO-ABWR-0006 and this RO, however the requirements of this RO should complement information Hitachi-GE is preparing to resolve RO-ABWR-0006, not replace it, and vice versa.

To be able to provide an adequate response to this RO, in undertaking the above work, ONR would expect:

- Hitachi-GE to consider all relevant Worldwide Operating Experience Feedback (OPEX) regarding materials degradation issues and threats in other Boiling Water Reactors (BWRs);
- Hitachi-GE to clearly state the applicability, or otherwise, of the above Worldwide OPEX to the UK ABWR design.

### References:

- [1] 1D-GD-0002 – UK ABWR GDA – Material Selection Report – Revision 0, Hitachi-GE, September 2014.
- [2] Safety Assessment Principles for Nuclear Facilities – Revision 0, ONR, 2014.
- [3] NS-TAST-GD-016 – Integrity of Metal Components and Structures – Revision 4, ONR, March 2013.
- [4] NS-TAST-GD-088 – Chemistry of Operating Civil Nuclear Reactors – Revision 0, ONR, April 2014. .
- [5] RO-ABWR-0006 – Source Terms, ONR/EA, April 2014, TRIM 2014/156113.
- [6] 1D-GD-0002 – UK ABWR GDA – Material Selection Report – Revision 1, Hitachi-GE, May 2015.
- [7] 1E-GD-5048 – Topic Report on Material Degradation Mechanisms – Flow-Accelerated Corrosion and Erosion-Corrosion – Revision 0, Hitachi-GE, May 2016.
- [8] 1E-GD-5051 – Topic Report on Material Degradation Mechanisms – Stress Corrosion Cracking – Revision 0, Hitachi-GE, June 2016.
- [9] RO-ABWR-0034, Demonstrating the Inclusion of a 'Bottom Drain Line' in the UK ABWR Achieves Inherent Safety and Reduces Risks SFAIRP, ONR, December 2014. TRIM 2014/118089.
- [10] UK ABWR GDA, ALARP Consideration on RPV Bottom Drain Line, SE-GD-0241, Rev. 2, Hitachi-GE, August 2016.

### **Regulatory Observation Actions**

**RO-ABWR-0035.A1** – Hitachi-GE to provide a robust justification for the materials selected for UK ABWR.

ONR's expectations for the reactor chemistry and structural integrity disciplines for Hitachi-GE's justification are aligned, in that ONR expects:

- Hitachi-GE to make materials selection and safety justifications for all UK ABWR SSCs that are

- proportionate to the significance of identified SSCs in maintaining nuclear safety;
- in doing so, Hitachi-GE to consider the nature, severity and likelihood of materials degradation in UK ABWR;
- Hitachi-GE to make a robust demonstration, showing that risks relating to materials degradation for UK ABWR are reduced SFAIRP.

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

**RO-ABWR-0035.A2** – Hitachi-GE to provide a robust justification for the materials selected for the feedwater piping in UK ABWR, in line with the regulatory expectations for Action 1.

The choice of feedwater piping material has an impact on the operating chemistry applied to UK ABWR. During Step 2 of GDA, ONR raised RQ-ABWR-0103 requesting Hitachi-GE to provide the basis for using carbon steel in the feedwater piping. As a consequence of the response to this RQ, ONR requested that the feedwater piping be one of the early examples in response to this RO.

ONR have subsequently reviewed the first response provided to Action 1 of this RO [6] and judge that the application of the methodology described therein to the feedwater piping in UK ABWR is inadequate.

The main reason for this is that Hitachi-GE have based their assessment on the assumption that the material selected will be some form of carbon steel as currently applied in J ABWR plants. As a consequence this means that it is necessary to inject oxygen to the feedwater to mitigate the risk of Flow Accelerated Corrosion. ONR consider that there are other potential material options which should be considered, including some which may not require active chemistry mitigations and therefore represent a higher level of inherent safety.

In addition to the expectations given in this RO and Action 1 above, ONR would also expect that:

- Hitachi-GE should demonstrate that other reasonably practicable options for material selection have been considered;
- Hitachi-GE should specifically consider the expectations of SAP EKP.1 regarding inherent safety in responding to this Action;

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

**RO-ABWR-0035.A3** – Hitachi-GE to provide suitable and sufficient evidence to support the claims made regarding material degradation risks and mitigations in the UK ABWR safety case.

The responses made to date under this RO provide a summary of Hitachi-GE's demonstration that the material choices for representative UK ABWR SSC's reduce risks SFAIRP. In line with the expectations of Action 1 of this RO, Hitachi-GE's responses provide a proportionate overview of key evidence to demonstrate that the judgements made in balancing the various materials related risks are appropriate. By their nature therefore, these responses do not contain all of the evidence that is necessary to support the claims made in the UK ABWR safety case regarding materials risks and importantly do not include an indication of what residual risks may remain, their safety significance, how likely they may be nor where they may occur when considering UK ABWR as a whole.

Alongside the responses to RO-ABWR-0035, Hitachi-GE plan to submit a suite of "material degradation" reports. ONR have assessed the first two of these, regarding Flow Assisted Corrosion (FAC) and Stress Corrosion Cracking (SCC) [7, 8]. While a welcome addition to the safety case, the scope and depth of evidence provided in these reports at present is insufficient to fully support the claims made in the UK ABWR safety case and does not provide the more holistic material degradation "risk assessment" that is necessary for UK ABWR.

This Action has therefore been raised to ensure that an adequate degree of evidence regarding material degradation risks and mitigations is provided during GDA of UK ABWR.

In addition to addressing the gap identified above, in responding to this RO-A ONR expect that:

- Hitachi-GE should provide suitable and sufficient evidence to support the claims made in the UK ABWR safety submissions;
- Hitachi-GE should consider how the evidence provided under this Action is related to other parts of the safety case for UK ABWR.
- Hitachi-GE should demonstrate that the risk of material degradation is ranked for the SSCs considered to be susceptible to degradation through-out the life of that SSC. This ranking should include a quantitative indication of the severity of the risks, to a degree that is necessary to support the claims; and
- Hitachi-GE should demonstrate that the residual risk from degradation mechanisms has been identified and can be managed appropriately, including identification of further actions or steps that a future Licensee may need to undertake.

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

**RO-ABWR-0035.A4** – Hitachi-GE to provide a robust justification for the material(s) selected for the ‘bottom drain line’ in UK ABWR, in line with the regulatory expectations for Action 1.

Early in Step 3 of GDA, ONR raised RO-ABWR-0034 [9], requesting Hitachi-GE provide a demonstration that the inclusion of a ‘bottom drain line’ in the UK ABWR design achieves inherent safety and reduces risks SFAIRP.

ONR has now received and assessed Hitachi-GE’s final submission [10] against RO-ABWR-0034. One of ONR’s main observations following an initial assessment of Reference 10, is that the report aims to do two things; provide the demonstration requested in Reference 9, but also, justify a materials change for the ‘bottom drain line’ in the UK ABWR design, relative to the reference plant. The reference plant uses carbon steel for the line, whereas Hitachi-GE’s current proposals for UK ABWR are to change the materials to either carbon steel with elevated trace chromium content, or low alloy steel.

ONR’s view is that whilst reference 10 does a much better job in seeking to answer the question of whether including a ‘bottom drain line’ in the UK ABWR design is justified or not, ONR has judged that the justification provided in reference 10 to change the materials for the ‘bottom drain line’ is not adequate, at this time. The main reason for this is that Hitachi-GE has made certain key assumptions when evaluating the benefits and detriments associated with the materials selected for the ‘bottom drain line’, which do not appear to have been appropriately ‘tested’. This includes, but is not limited to:

- Taking credit for the combination of operating chemistry and new materials selected for the line, to claim it results in lower doses to workers (relative to the reference plant);
- Inconsistent application of arguments relating to the risk of introducing un-intended consequences as a result of design/materials changes;
- No consideration of the potential detriments of dissimilar metal welding in the ‘bottom drain line’ and the impact this may have on the evaluation of LOCA risk.

The justifications for retaining the ‘bottom drain line’ in the UK ABWR design and the choice of materials for it are inextricably linked. Hitachi-GE’s claim in Reference 10 is that part of the reason why it is ‘ALARP’ to retain the ‘bottom drain line’, overall, is due to the change in materials suggested along with the combination of the UK ABWR operating chemistry, providing an overall net safety benefit.

This Action has therefore been raised to ensure that a robust justification for the material(s) selected for the ‘bottom drain line’ is provided during GDA of UK ABWR and that any potential materials changes to the ‘bottom drain line’ for UK ABWR, relative to the reference plant, have a sound basis and are appropriately justified.

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

**REQUESTING PARTY TO COMPLETE**

**Actual Acknowledgement date:**

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RP stated Resolution Plan agreement date:	
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