REGULATORY OBSERVATION

REGULATOR TO COMPLETE

RO unique no.:	RO-UKHPR1000-0034
Revision:	0
Date sent:	02/03/20
Acknowledgement required by:	23/03/20
Agreement of Resolution Plan Required by:	30/04/20
TRIM Ref:	2020/24279
Related RQ / RO No. and CM9 Ref: (if any):	RQ-UKHPR1000-0094 (CM9 2018/199866), RQ-UKHPR1000-0457 (CM9 2019/354408), RQ-UKHPR1000-0561 (CM9 2020/7196)
Observation title:	Minimisation of flow accelerated corrosion (FAC) risks so far as is reasonably practicable (SFAIRP)
Lead technical topic: 1. Chemistry	**Related technical topic(s):** 20. Structural Integrity

Regulatory Observation

Background

Flow Accelerated Corrosion (FAC) refers to enhanced dissolution of the passive, and usually protective, oxide layers on the surface of carbon and Low-Alloy Steels (LAS). It is a chemical effect that is primarily influenced by pH, hydrodynamics, material composition, oxygen concentration and temperature. FAC can occur in flowing water or wet steam, under single- or two-phase flow conditions and can be particularly prevalent under the conditions that can occur around the secondary circuit of a Pressurised Water Reactor (PWR). Not only can FAC lead to rapid failures of components, it is also implicated as a significant source of Corrosion Product (CP) transport around the secondary circuit. Material degradation by FAC can have serious safety consequences, with two events at PWRs having resulted in fatalities in the past.

FAC susceptibility can be reduced using (or a combination of):

- Flow conditions
- Materials selection (especially chromium content)
- Water chemistry

The RP makes the following claim (Ref. 1) in relation to FAC:

- *Sub claim 3.3.10.4: The effects of ageing of the chemistry related systems important to nuclear safety have been addressed in the design and selection of an optimum chemistry regime.*

During Step 2 and 3 of Generic Design Assessment (GDA), the Requesting Party (RP) provided some limited information on consideration given to FAC in UK HPR1000 (Refs. 1 to 3). The RP's basis for FAC mitigation is a combination of the selection of FAC resistant materials and the optimisation of pH at a number of FAC susceptible areas. I was content that materials selection and chemistry control to minimise FAC susceptibility were reasonable arguments during Step 3, on the basis that further details of the analysis carried out and substantiation for these arguments would be required as GDA progressed. On this basis, towards the end of Step 3 I raised RQs (RQ-UKHPR1000-0457 and RQ-UKHPR1000-0561 (Refs. 4 and 5)) to request details of the evidence supporting claims and arguments in this area, particularly on how control of FAC has been designed into the secondary circuit for susceptible areas and components.

In its response to RQ-UKHPR1000-0457, the RP noted that FAC analysis had been performed for HPR1000 and reiterated its claims (as presented in Ref. 3) on material selection, chemistry control and design optimisation to reduce FAC risk. In RQ-UKHPR1000-0561 I requested details of the analysis that had been carried out, in order to assess the adequacy of the RP's approach to identifying FAC susceptible areas of the plant and the adequacy of the justification provided for the FAC mitigation measures specified. The response to RQ-UKHPR1000-0561 did not contain information on the approach used by the RP to evaluate FAC risk, nor did it provide evidence (or confidence that appropriate evidence will be provided during Step 4) to support the RP's claims and arguments that materials selection, chemistry control and design optimisation reduce FAC risk SFAIRP in UK HPR1000.

The RP's current approach of justifying materials choices and chemistry is insufficient to demonstrate effective protection of at risk areas of the plant, and to identify any residual FAC risks that may need to be managed by a future licensee.

This Regulatory Observation (RO) is therefore raised to:
- Explain ONR's regulatory expectations;
- Obtain confidence that suitable and sufficient evidence will be provided by the RP to support the claims and arguments made in the UK HPR1000 generic safety case;
- Assist ONR's judgement as to whether a robust demonstration has been made that the risks associated with FAC have been reduced SFAIRP in the design of UK HPR1000.

Relevant Legislation, Standards and Guidance

The chemistry section of ONR's Safety Assessment Principles (SAPs) (Ref. 6) contains SAP ECH.1:

Engineering principles: chemistry	Safety cases	ECH.1
Safety cases should, by applying a systematic process, address all chemistry effects important to safety.		

Paragraph 513 of reference 6 provides further detail, noting that:

"The analysis should include: (a) reactions between chemicals and other materials within the process, plant or facility, including, for example, corrosion…"

Also of relevance is SAP EAD.1:

Engineering principles: ageing and degradation	Lifetime margins	EAD.2
Adequate margins should exist throughout the life of a facility to allow for the effects of materials ageing and degradation processes on structures, systems and components.		

Paragraph 218 of reference 6 provides further detail, noting that:

"The effects of, and interactions between the mechanical, thermal, chemical, physical, biological and radiation environment on materials properties, materials ageing and degradation processes should be considered."

The ONR Technical Assessment Guide (TAG) on the Chemistry of Operating Civil Nuclear Reactors (Ref. 7) further supports these SAPs, noting that the inspector may consider whether the RP has *"adequately identified and reviewed the corrosion threats to the plant, based on the materials of construction and operating environment (ECH.1). This is specific to the plant design, including operating conditions and should consider all modes of operation."*

The ONR Technical Assessment Guide (TAG) on Chemistry Assessment (Ref. 8) also notes that the inspector may consider whether there is a "*clear demonstration that the starting point for mitigating materials degradation threats is not to place reliance on active chemistry control(s), where it is reasonably practicable not to do so.* SAP EKP.1 (Ref. 6) is particularly pertinent in relation to this point, as some degradation threats can effectively be eliminated by informed materials selection decisions.

Regulatory Expectations

ONR expect the claims and arguments presented in the RP's Pre-Construction Safety Report (PCSR) and supporting references to be adequately substantiated by suitable and sufficient evidence. ONR would therefore expect the RP's safety case for UK HPR1000 to:
- Provide suitable and sufficient evidence to support the claims made in the UK HPR1000 safety submissions that materials selection, chemistry control and design optimisation reduce FAC risk SFAIRP in UK HPR1000;

- Demonstrate that the relevant safety risks relating to materials degradation by FAC for UK HPR1000 are reduced SFAIRP;
- Identify any residual FAC risks, including identification of further actions or steps that a future Licensee may need to undertake.

References

[1] Pre-Construction Safety Report Chapter 21 Reactor Chemistry, HPR/GDA/PCSR/0021, Rev 000, September 2018. CM9 ref. 2018/316411.
[2] Application Analysis of Alkaline Agent in the Secondary Circuit, Rev. B, 28 June 2019, CM9 Ref. 2019/187232.
[3] RQ-UKHPR1000-0094 Clarification of Chemistry-related Aspects of the Design of the UK HPR1000 Secondary Circuit, Full Response, 15 June 2018. CM9 ref. 2018/199866.
[4] RQ-UKHPR1000-0457 PCSR Chapter 21 Queries, Full Response, 29 November 2019. CM9 ref. 2019/354408.
[5] RQ-UKHPR1000-0561 Follow-up Query on Secondary Circuit Chemistry FAC, Full Response, 6 January 2020. CM9 ref. 2020/7196.
[6] Safety Assessment Principles for Nuclear Facilities 2014 Edition, Revision 1, January 2020, CM9 Ref. 2019/367414.
[7] NS-TAST-GD-088 Chemistry of Operating Civil Nuclear Reactors, Revision 2, January 2019, CM9 Ref. 2019/9175.
[8] NS-TAST-GD-089 Chemistry Assessment, Revision 0, February 2018, CM9 Ref. 2017/202952.

Regulatory Observation Actions

RO-UKHPR1000-0034.A1 – Provide suitable and sufficient evidence to support the claims made regarding FAC risks and mitigations in the UK HPR1000 safety case.

The overall intent for this Regulatory Observation Action (ROA) is for the RP to identify the relevant safety risks associated with FAC in UK HPR1000 and provide a robust demonstration that they are reduced SFAIRP, including the provision of suitable and sufficient evidence to support the justification.

Therefore in response to this ROA, ONR would expect GNS to:

- Justify the approach/methodology used to evaluate FAC risks in UK HPR1000, taking into account all relevant influencing factors, for example plant environmental conditions, material composition, and flow conditions;
- Based on the above, identify the lines and components in the UK HPR1000 secondary circuit that are considered susceptible to material degradation by FAC. ONR would expect this to include suitable and sufficient information/evidence pertaining to the severity/likelihood of degradation by FAC;
- Identify and document the options considered to eliminate, reduce or mitigate the risks of materials degradation due to FAC in the susceptible areas identified;
- Make an appropriate overall demonstration that relevant risks relating to materials degradation by FAC for UK HPR1000 have been reduced SFAIRP. As part of this, provide suitable and sufficient evidence to justify the option(s) selected to eliminate, reduce or mitigate the risks of materials degradation due to FAC. Additionally provide robust evidence of the criteria used in decision making and option selection;
- Demonstrate that any residual risks from FAC have been identified, including identification of further actions or steps that a future Licensee may need to undertake.

Resolution required by '*to be determined by General Nuclear System Resolution Plan*'

REQUESTING PARTY TO COMPLETE

Actual Acknowledgement date:	
RP stated Resolution Plan agreement date:	