REGULATORY OBSERVATION

REGULATOR TO COMPLETE

RO unique no.:	RO-UKHPR1000-0049
Revision:	0
Date sent:	14/08/20
Acknowledgement required by:	04/09/20
Agreement of Resolution Plan Required by:	11/09/20
CM9 Ref:	2020/222453
Related RQ / RO No. and CM9 Ref: (if any)**:**	RQ 814 - Control of Tritium (2020/192414), RO-UKHPR1000-0026 – Minimisation of radioactivity and demonstration that associated risks are reduced So Far As Is Reasonably Practicable (SFAIRP) (2019/312783), RO-UKHPR1000-0031 - Control of Boron during Normal Operations and Faults (2019/3636067)
Observation title:	Generation, Transport and Behaviour of Tritium during Normal Operations
Lead technical topic: 1. Chemistry	**Related technical topic(s):** 16. Radiological Protection 17. RadWaste, Decommissioning & Spent Fuel Management 21. Environmental

Regulatory Observation

Background

Tritium is a radioactive isotope of hydrogen; it is a low energy beta emitter with a half-life of approximately twelve years. In a civil Pressurised Water Reactor (PWR), such as the UK HPR1000, tritium can be generated in significant quantities via various mechanisms:

- Fission of nuclear fuel – where a small percentage can diffuse through the cladding of the fuel into the primary coolant;
- Neutron activation of primary circuit constituents, in particular boron and lithium, which are both essential components of the primary circuit chemistry regime; and
- Neutron activation of specific materials, such as Secondary Neutron Sources, (from beryllium that is present in the source) and some control rods.

Once generated, tritium cannot be completely eliminated or removed by treatment/abatement systems, so it must be safely managed and ultimately discharged of, either as gaseous or aqueous waste. For the UK HPR1000, the Requesting Party (RP) has identified various measures to minimise the generation of tritium, which include: the selection of an appropriate fuel cladding material, optimisation of the lithium and boron concentrations in the primary circuit (including the use of enriched lithium), and optimisation of both the use of secondary neutron sources and their materials of construction, (Refs. 1 – 3).

Despite the measures implemented to reduce the generation of tritium, in PWRs, it is still produced in quantities which are significant enough to present a radiological hazard to workers. It is therefore important to have a robust understanding of its generation, transport and distribution around the plant, to be able to identify adequate controls to reduce the risk of an inadvertent radiological exposure, to as low as reasonably practicable (ALARP).

Although the RP estimates that doses to the public from tritium are a small percentage of the overall collective dose, they estimate that the total annual realistic tritium production for UK HPR1000 to be relatively significant (Ref. 2, 4 and 5), as would be expected for a civil PWR plant.

As well as providing an estimated total quantity for tritium production as an annualised average, the RP has presented a very narrow set of limits and conditions necessary in the interests of safety, associated with tritium control. The information underpinning the RP's estimate for tritium production in UK HPR1000 and ergo, the associated limits and conditions, is based on OPEX from Chinese PWRs which have different design features and are operated in a different way, to the intended operations for UK HPR1000. Some of these differences will impact both the generation and overall behaviour of tritium in UK HPR1000, for example, the:

- Decision to implement Enriched Boric Acid in the primary circuit operating chemistry regime; and the
- Requirement to operate the plant to recycle primary coolant, amongst other things.

ONR has previously raised two Regulatory Observations (ROs) seeking an adequate justification that radioactivity has been reduced SFAIRP in UK HPR1000 (Ref. 6) and further information to demonstrate boron can be adequately controlled during normal operations (Ref. 7). ONR's assessment of the information provided to date to respond to Refs. 6 and 7, and also of the RP's suite of documents which define and justify the normal operational source term(s) for UK HPR1000, have revealed persistent shortfalls in the information provided, related to tritium. These shortfalls mean that at present, the generic safety case does not:

- Adequately reflect the design and intended operations for UK HPR1000, with respect to the impact on the generation, transport and behaviour of tritium;
- Provide suitable and sufficient information to justify the claimed behaviour of tritium in UK HPR1000; nor
- Provide a suitable basis to underpin the identification of suitable and sufficient measures to control tritium in UK HPR1000.

This RO has therefore been raised to:

- Explain ONR's regulatory expectations;
- Obtain confidence that adequate evidence will be provided by the RP to support the claims and arguments made in the UK HPR1000 generic safety case; and
- Assist ONR's judgement of whether a robust demonstration that tritium is adequately understood and appropriate controls will be identified, will be produced.

<u>Relevant Legislation, Standards and Guidance</u>

The chemistry section of ONR's Safety Assessment Principles (SAPs), (Ref. 8), 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 511 of Reference 8 then goes onto state:

"The safety case should identify and analyse how chemistry can impact safety during normal operations and in fault and accident conditions, and demonstrate how the chemistry will be controlled."

Also of relevance is SAP ECH.3 and ECH.4:

Engineering principles: chemistry	Control of chemistry	ECH.3
Suitable and sufficient systems, processes and procedures should be provided to maintain chemistry parameters within the limits and conditions identified in the safety case.		

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.		

Regulatory Expectations

ONR expect the claims and arguments presented in the safety case to be adequately substantiated by suitable and sufficient evidence. ONR would therefore expect the generic safety case to include a robust analysis and demonstration that tritium is adequately managed by the design and intended operational practices for UK HPR1000.

Based on the expectations re-produced from the standards and guidance listed above, ONR expects the generation, transport and behaviour of tritium during normal operations to be adequately understood and controlled, and the risks associated with tritium to be reduced SFAIRP. To be able to achieve this demonstration, as part of the resolution of this RO, the RP will need to undertake and document the following activities:

- Demonstrate that the behaviour of tritium in the UK HPR1000 is adequately understood and estimated;
- Provide appropriate analysis to underpin the claimed generation, transport and behaviour of tritium in the primary circuit and associated systems, and of tritium “leaving” the primary circuit, considering plant-specific aspects of the UK HPR1000 design, such as the use of Enriched Boric Acid and primary coolant recycling;
- Demonstrate that relevant risks associated with the management of tritium have been reduced SFAIRP.

ONR recognises there are operator-specific choices related to the management of tritium which will impact its overall behaviour in UK HPR1000. As well as addressing the expectations listed above, for Generic Design Assessment (GDA), ONR expects sufficient information to be provided to demonstrate whether the generic design imparts any specific constraints which may foreclose any available tritium management strategies from being adopted in the future; and to justify that adequate controls are in place to enable these strategies to be safely implemented.

References

[1] *Pre-Construction Safety Report, Chapter 21, Reactor Chemistry*, HPR/GDA/PCSR/0021, Rev. 000, GNS, November 2018. www.ukhpr1000.co.uk/wp-content/uploads/2018/11/HPR-GDA-PCSR-0021-Pre-Construction-Safety-Report-Chapter-21-Reactor-Chemistry.pdf
[2] *Minimisation of the Discharge and Environment Impact of Tritium*, GHX00100004DOHB00GN, Rev C, CGN, November 2019. CM9 Ref: 2019/357768.
[3] *Minimisation of Radioactivity Route Map Report,* GHX00100002DNHS03GN, Rev C, CGN, May 2020. CM9 Ref: 2020/130809.
[4] *Primary Coolant Source Term Calculation Report,* GHX00800006DRDG03GN, Rev C, CGN, October 2019. CM9 Ref: 2019/318380.
[5] *Derived Source Term Supporting Report,* GHX00530001DNFP03GN, Rev B, CGN, August 2019. CM9 Ref: 2019/252639.
[6] RO-UKHPR1000-0026 – Minimisation of radioactivity and demonstration that associated risks are reduced So Far As Is Reasonably Practicable (SFAIRP), 2019/312783.
[7] RO-UKHPR1000-0031 - Control of Boron during Normal Operations and Faults, 2019/3636067.
[8] *Safety Assessment Principles for Nuclear Facilities*, 2014 Edition, Revision 0, Office for Nuclear Regulation, 2014. www.onr.org.uk/saps/saps2014.pdf

Regulatory Observation Actions

RO-UKHPR1000-0049.A1 – Demonstrate that the behaviour of tritium in the UK HPR1000, during normal operations, is adequately understood and controlled

The overall intent for this Regulatory Observation Action (ROA) is for the RP to identify the relevant safety risks associated with tritium 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.

In response to this Action the RP should:

- Provide suitable and sufficient analysis to underpin the claimed generation, transport and behaviour of tritium in the primary circuit and associated systems, and of tritium "leaving" the primary circuit, considering plant-specific aspects of the UK HPR1000 design, such as the use of Enriched Boric Acid and primary coolant recycling. This analysis should quantify and justify the levels of tritium entering other systems in the nuclear island, such as the Spent Fuel Pool and the in-containment refuelling water storage tank (IRWST).
- The analysis should include a consideration of how any operator actions may affect the transport of tritium, and if this results in any additional operating constraints. This analysis should also identify if the generic design imparts any specific constraints on future operators, with respect to the implementation of future tritium management strategies.
- Using the analysis described above; identify any relevant controls, including any limits and conditions necessary in the interests of safety, required to safely manage tritium throughout the plant.
- Based upon the above analysis, make an appropriate overall demonstration that relevant risks associated with the management of tritium in UK HPR1000, have been reduced SFAIRP.

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:	