REGULATORY OBSERVATION

REGULATOR TO COMPLETE

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Revision:	0
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Agreement of Resolution Plan Required by:	31/03/20
CM9 Ref:	2019/363067
Related RQ / RO No. and CM9 Ref: (if any):	n/a
Observation title:	Control of Boron during Normal Operations and Faults
Lead technical topic: 1. Chemistry	**Related technical topic(s):** 9. Fault Studies 10. Fuel & Core 17. RadWaste, Decommissioning & Spent Fuel Management 21. Environmental

Regulatory Observation

Background

Boron, in the form of boric acid, is dissolved in the primary coolant of the UK HPR1000 to regulate rates of nuclear reaction at-power and as a backup to the shutdown control-rods at other times. Stocks of coolant for use in emergencies, shutdowns and the Spent Fuel Pool are also held with a sufficiently high Boron concentration to completely suppress nuclear chain reaction. At-power, the concentration of Boron in the circulating primary coolant is modified to compensate for variations in the fissile content of the fuel and contraction of the coolant in a shutdown. The amount of Boron required at any given time is determined by nuclear physics. This means that the operators must have rigorous control over Boron at all times. The main nuclear safety risks associated with a loss of control of Boron relate to dilution events, covering both heterogeneous and homogeneous dilution events.

For UK HPR1000 the Requesting Party (RP) has specified that Enriched Boric Acid, (EBA), will be used rather than natural Boron. In natural boric acid, only around 21% of the Boron is the effective ^{10}B isotope but this percentage is increased in EBA. While the use of EBA offers some potential safety benefits, it does require additional controls as, in addition to the overall concentration of Boric acid, the enrichment must be strictly controlled to ensure that there is no inadvertent reduction in the ^{10}B content. Such a process also happens throughout the fuel cycle by the poisoning effect of the Boron. The UK HPR1000 will recycle the EBA that is used, which involves the interaction of several different systems. A key part of the safety case is therefore the control of Boron concentration, (both chemical and isotopic), within all the relevant systems, and a justification that the systems that control Boron chemistry are adequate.

As well as the PCSR [1], during Step 3 of GDA, ONR has continued to receive and assess the RP's suite of supporting documentation which defines and justifies the chemistry for UK HPR1000, including [2]. To support the safety arguments presented in [1], and to be able to provide an adequate demonstration of how Boron is controlled in UK HPR1000, ONR expect this suite of documents to provide information on the Boron recycling system and the control of Boron, the choice and justification of the enrichment level of Boron, the monitoring, control and handling of Boron, and the prevention of Boron dilution events, (both chemical and isotopic, during normal operations and in fault conditions). This should cover the full range of systems where a claim is made on the Boron to provide nuclear reactivity control, and over all relevant operating modes.

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Without this information there is currently a shortfall in the UK HPR1000 generic safety case. When this matter has been discussed during routine technical Level 4 meetings with the RP, it has not been possible for ONR to discern how the RP intends to address this matter.

This Regulatory Observation (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 Boron chemistry can be adequately controlled will be produced.

Relevant Legislation, Standards and Guidance

The chemistry section of ONR's Safety Assessment Principles (SAPs) [3] 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 5 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.		

This is further supported in ONR's Technical Assessment Guide (TAG), *Chemistry of Operating Civil Nuclear Reactors* [4]. Paragraph 5.13 of which states:

"If such a control requires a particular isotope (e.g. ^{10}B) then the controls over this particular isotope merit attention, particularly the quality control, purity and measurement arrangements (ECH.4 and ERC.4)"

The reactor core section of ONR's Safety Assessment Principles (SAPs) [4] contains SAP ERC.3:

Engineering principles: reactor core	Stability in normal operation	ERC.3
The core should be stable in normal operation and should not undergo sudden changes of condition when operating parameters go outside their permitted range.		

The supporting Paragraph 550 of Reference 4 states:

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"The effects of changes in coolant condition or composition on the reactivity of the reactor core should be identified."

Regulatory Expectations

ONR expect the claims and arguments presented in the PCSR to be adequately substantiated by suitable and sufficient evidence. ONR would therefore expect the safety case to include an adequate description of all aspects of Boron chemistry, including under fault conditions.

Based on the expectations re-produced from the standards and guidance listed above, ONR expects Boron chemistry to be adequately controlled and the risks associated with Boron dilution 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:

- Provide a description of the Boron cycle including the chemistry requirements for all parts of the system, clearly identifying the justification that the various systems that form part of the Boron recycling system have been substantiated to perform the appropriate role. This should also include any monitoring and controls required, and any specific handling requirements
- Provide a coherent justification for the choice of enrichment level selected for Boric acid use
- Adequately demonstrate how the risk of Boron dilution faults have been mitigated, both chemical and isotopic dilutions, during normal operations and in fault conditions

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] *Topic Report on Power Operation Chemistry,* GHX00100104DCHS03 GN, Rev B, CGN. April 2019. CM9 Ref: 2019/152125.
[3] *Safety Assessment Principles for Nuclear Facilities*, 2014 Edition, Revision 0, Office for Nuclear Regulation, 2014. www.onr.org.uk/saps/saps2014.pdf
[4] *Nuclear Safety Technical Assessment Guide, Chemistry of Operating Civil Nuclear Reactors*, NS-TAST-GD-088 Revision 2, Office for Nuclear Regulation, 2019.
www.onr.org.uk/operational/tech_asst_guides/index.htm

Regulatory Observation Actions

RO-UKHPR1000-0031.A1 – Demonstrate that Boron can be adequately controlled during normal operations

In response to this Action the RP should:

- Provide a suitable and sufficient safety case to demonstrate that Boron can be controlled in all systems where a nuclear safety claim is made on it, and covering all operating modes.
- Provide a description of all systems that are involved in controlling Boron in the UK HPR1000. This should be a rigorous review detailing how Boron is controlled in all aspects of the systems during normal operation. This should include a description of how the concentration is controlled, and how the normal dilution process is governed. In addition to the Primary Circuit this review should include the following systems:

    - Chemical Volume and Control System
    - Condensate Storage and Treatment System
    - Reactor Boron Water Make-up System
    - Emergency Boration System
    - Safety Injection System
    - Spent Fuel Pool
    - In-Containment Refuelling Water Storage Tank

  This review should also identify relevant control parameters, and any limits and conditions that should be applied. Where aspects of the substantiation is provided in existing documents, clear links should be identified to justify that the systems have been substantiated to fulfill the requirements that have been placed upon them.

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- Justify the use of Enriched Boric Acid, and the choice of enrichment level. This should consider the effect this choice has on the operating pH throughout the fuel cycle, any impacts the use of EBA has on the production of radioactivity, and any impact on refuelling activities.
- Identify the specific operating and handling requirements associated with the use of EBA, including make-up and preparation of EBA.
- Describe how Boron enrichment will be controlled, and identify the different scenarios that may have an impact on Boron depletion. Identify the necessary actions that will be required to control Boron enrichment throughout the fuel cycle.
- Demonstrate that the monitoring and sampling systems have been designed to achieve representative sampling of all relevant locations within the primary circuit and other relevent systems.

The response to this ROA may be combined with any other ROA under this RO, if deemed appropriate.

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

RO-UKHPR1000-0031.A2 – Demonstration that the risks associated with Boron Dilution Faults have been reduced SFAIRP

- Provide a suitable and sufficient justification that the risks associated with Boron dilution faults have been reduced SFAIRP in the generic UK HPR1000 design. This should include:

  - Identification of the fault scenarios that could lead to a homogeneous dilution of the expected Boron concentration, and the consequences of such events.
  - Identification of the fault scenarios that could lead to a heterogeneous dilution of the expected Boron concentration, and the consequences of such events.
  - Justification that the systems that are employed to detect a Boron dilution fault are adequate.
  - Demonstration that the processes and systems that are designed to protect against Boron dilution faults are capable of delivering the required safety functions with sufficent reliablility.
  - A description of the measures that are necessary to prevent the inadvertant use of Boric acid with insufficient enrichment.

- The response to this Action should consider all systems where a nuclear safety claim is made on Boron, and cover all operating modes.

The response to this ROA may be combined with any other ROA under this RO, if deemed appropriate.

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:	

Protective Marking (if required)