REGULATORY OBSERVATION

REGULATOR TO COMPLETE

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Revision:	0
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Acknowledgement required by:	02/01/20
Agreement of Resolution Plan Required by:	31/01/20
TRIM Ref:	2019/339671
Related RQ / RO No. and TRIM Ref: (if any)**:**	
Observation title:	Debris effects on Safety Injection System and Containment Heat Removal System performance
Lead technical topic: 9. Fault Studies	**Related technical topic(s):** 1. Chemistry 10. Fuel & Core 14. Mechanical Engineering 19. Severe Accident Analysis 20. Structural Integrity

Regulatory Observation

Background

Debris mobilised during an accident can impact the performance of the Safety Injection System (RIS [SIS]) and Containment Heat Removal System (EHR [CHRS]) during both design basis and design extension conditions. Such debris can arise from latent sources within the containment or from insulation material used to reduce heat losses from in-containment piping and components. ONR considers that the Requesting Party (RP) for the UK HPR1000 has not yet presented an adequate safety case regarding the potential detrimental effects of such debris on the RIS [SIS] and EHR [CHRS] during accident conditions. This Regulatory Observation presents ONR's expectations of the scope of such a safety case within the Generic Design Assessment (GDA) of the UK HPR1000.

In the UK HPR1000 design the In-containment Refuelling Water Storage Tank (IRWST) supplies boronated water to the RIS [SIS] and EHR [CHRS] during design basis and design extension conditions. In a high energy pipe failure event, debris generated from the insulation material (as a result of jet impingement or pipewhip) and latent debris (i.e. pre-existing debris) could be swept in to the IRWST sump. This debris has the potential to impair short and long term heat removal through blockage of filters or pipes, degradation of heat transfer and damage of equipment. It is, therefore, necessary to take those effects in to account when designing the RIS [SIS] and EHR [CHRS] systems and associated filtration technology, and performing optioneering for the choice of insulation material within the containment.

Through engagements with the Requesting Party (Ref. 2), ONR is content that the Requesting Party recognises the potential effects of debris on the RIS [SIS] and EHR [CHRS]. In addition, the Requesting Party has identified requirements for the RIS [SIS] filtration system at Reference 1 (Section 4.2.5.6); however, the derivation of these requirements at Reference 1 has not been provided, nor evidence to demonstrate that the requirements will be met by the design.

As a result of engagements with the Requesting Party, *ALARP analysis for insulation material selection in primary loop, Rev A, July 2019* (Ref. 3) was submitted to ONR. The Requesting Party has recognised that the choice of insulation materials for the primary circuit is a significant factor in determining the debris source term, but has stated that the performance of the RIS [SIS] and EHR [CHRS] is not a key factor in determining a position in which risks have been reduced As Low As Reasonably Practicable (ALARP). Reference 3 concludes that reflective metallic insulation presents the ALARP option for major components of the primary circuit and the steam generator shell and states that the insulation of other components will be considered at a later date.

ONR considers that an assessment of the effects of debris on the performance of the RIS [SIS] and EHR [CHRS] is a key aspect to demonstrating that risks have been reduced ALARP. Therefore, ONR considers that the safety case requires further development to consider the debris effects on the performance of the RIS [SIS] and EHR [CHRS]. Ultimately, the safety case should present evidence that all functional requirements on the RIS [SIS] and EHR [CHRS] can be met in the presence of debris, confirm that adequate short and long term heat removal will be achieved in accident conditions, and demonstrate that residual risks have been reduced ALARP.

Relevant Legislation, Standards and Guidance

The following Safety Assessment Principles (Ref. 4), and associated paragraphs, are relevant to this RO:

The regulatory assessment of safety cases	Safety case characteristics	SC.4
A safety case should be accurate, objective and demonstrably complete for its intended purpose.		

102. To demonstrate that risks have been reduced to ALARP, the safety case should: (a) identify and document all the options considered for risk prevention or reduction; (b) provide evidence justifying the criteria used in decision making or option selection; (c) justify the options chosen in terms of meeting relevant good practice, and discard any options as being either less effective than the chosen option(s) or grossly disproportionate.

Engineering principles: key principles	Defence in depth	EKP.3
Nuclear facilities should be designed and operated so that defence in depth against potentially significant faults or failures is achieved by the provision of multiple independent barriers to fault progression.		

Fault analysis: design basis analysis	Fault tolerance	FA.4
DBA should be carried out to provide a robust demonstration of the fault tolerance of the engineering design and the effectiveness of the safety measures.		

Fault analysis: design basis analysis	Fault sequences	FA.6
For each initiating fault within the design basis, the relevant design basis fault sequences should be identified.		

632. The analysis should establish that adverse conditions that may arise as a consequence of the fault sequence will not jeopardise the claimed performance of the safety measures.

International experience has shown that there are a number of relevant factors in assessing the performance of heat removal systems in the presence of debris (Refs 5, 6, 7 and 8). International test and assessment projects are on-going for a number of reactor designs in order to demonstrate safety claims, and this topic continues to attract international regulatory attention.

Regulatory Expectations

ONR considers that the RP should consider the potential effects of debris on emergency core cooling and containment heat removal during accident conditions. Specifically, ONR considers that an assessment of the

RIS [SIS] and EHR [CHRS] in the presence of debris generated by accidents should be performed, and that the output of this analysis should be used to inform the demonstration that the residual risks are ALARP. ONR expects that the assessment will include, but is not limited to, the following factors:

- Debris source term - the quantity and characteristics of the debris should be adequately justified, including making use of relevant analysis and testing. A number of factors should be considered when determining the debris source term, including:
    - the quantity of latent debris;
    - the quantity of debris from insulation material;
    - the break location and zone of influence (ZoI) of jet impingement and pipe whip;
    - material types within the ZoI;
    - transportation of debris from the break to the IRWST; and
    - chemical effects in the IRWST.
- Filtration performance – The assessment of filtration technology performance should be based on data which is adequately representative of the plant. In order to calculate the amount and characteristics of any debris that is not filtered, the assessment should include considerations of the filtration technology, filter cake formation and the effect of back-flushing (including the potential for back-flushing to increase debris bypass);
- Pump performance – An assessment should be performed to ensure that the safety functional requirements of the pumps can be met in all accident conditions. This includes demonstrating a margin to the required Net Positive Suction Head and that the pumps are qualified to operate for all downstream debris source terms identified;
- Heat removal – Testing and analysis on the reduction in heat removal capability should demonstrate any reduction in heat removal as a result of any blockage or coating of fuel is tolerable. The level of confidence and conservatism in the analysis should be appropriate to the accident conditions considered.

The above list is not intended to be exhaustive and a suitable and sufficient justification should be provided, dependant on the accident conditions considered by the RP.

In addition to the above, ONR considers that the RP should demonstrate that the different levels of Defence in Depth are sufficiently independent in order to avoid common cause failure of the RIS [SIS] and EHR [CHRS].

References

1. CGN, GDA-REC-CGN-002391 - Pre Construction Safety Report - Chapter 7 Supporting Reference - RIS Safety Injection System Design Manual – Chapter 4 System & Component Design A - 2 October 2018
2. 2018/51945 ONR-NR-CR-17-679 - UK HPR1000 - Level 4 Mechanical Engineering Meeting - 29 January 2018 - 2 February 2018
3. CGN, GHX44750001DPZS44GN, ALARP analysis for insulation material selection in primary loop, Rev A, July 2019.
4. ONR, Safety Assessment Principles for Nuclear Facilities, Office for Nuclear Regulation, April 2014
5. MDEP Design Specific Common Position CP-APR1400-02. Common Positions on the APR1400 Post Loss Of Coolant Accident (LOCA) Strainer Performance and Debris In-Vessel Downstream Effects, Version 1, dated August 2017.
6. U.S. Nuclear Regulatory Commission Regulatory Guide 1.82. Water Sources for Long-term Recirculation Cooling Following a Loss-of-Coolant Accident, Revision 4, dated March 2012
7. GSI-191: The impact of Debris Induced loss of ECCS Recirculation on PWR Core Damage Frequency, NUREG/CR-6771
8. Containment Emergency Sump Performance (Technical Findings Related To Unresolved Safety Issue A-43), NUREG-0897

Regulatory Observation Actions

RO-UKHPR1000-0027.A1 – Review of Relevant Good Practice

In response to this Regulatory Observation Action, GNS should:

Perform a review of relevant good practice relating to the impact of debris on the performance of the UK HPR1000 design during accident conditions. This should include:

- A review of international regulatory requirements, guidance and other publications related to the topic;
- Any relevant test facilities and research, a review of the findings and whether those data can be used to support the resulting UK HPR1000 safety case;
- Filtration technology and insulation material design solutions adopted by other reactor vendors in the UK and internationally.

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

RO-UKHPR1000-0027.A2 – Identification of safety relevant factors

In response to this Regulatory Observation Action, GNS should identify:

- All accident conditions in which a demand on the RIS [SIS] or EHR [CHRS] is made, and identify limiting scenerios.
- The quantity and characteristics of the debris that may result for such accidents.
- Any safety functions that may be challenged as a result of debris in the IRWST during design basis and design extension conditions.
- All relevant factors that need to be considered to demonstrate that the required safety functions will be delivered during design basis and severe accident conditions.
- The derivation of the performance requirements for any relevant SSCs (including primary circuit insulation material, sump filters and RIS[SIS] and EHR[CHRS] pumps etc).

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

RO-UKHPR1000-0027.A3 – Demonstrate that risks associated with debris effects during accidents in UK HPR1000 have been reduced ALARP

In response to this Regulatory Observation Action GNS should develop a suitable and sufficinet safety case regarding debris effects on the SIS[RIS] and EHR[CHRS]. This should include the following:

- The review performed for RO-UKHPR1000-0027.A1
- The outcome of RO-UKHPR1000-0027.A2
- Presentation of a justification for the adequacy of the UK HPR1000 design against potential debris in the IRWST, including appropriate claims, arguments and evidence.
- A clear demonstration that the residual risks associated with debris effects are reduced ALARP for the generic design.
- Identification of any additional work that is required in order to demonstrate the adequacy of the UKHPR1000 design against potential debris in the IRWST, including any further work that may be required post-GDA (e.g. commissioning tests or research activities).

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:	