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REGULATORY OBSERVATION Resolution Plan	
RO Unique No.:	RO-UKHPR1000-0027
RO Title:	Debris effects on Safety Injection System and Containment Heat Removal System performance
Technical Area(s)	Fault Studies
Revision:	0
Overall RO Closure Date (Planned):	30/04/2021
Linked RQ(s)	-
Linked RO(s)	-
Related Technical Area(s)	Chemistry Fuel & Core Mechanical Engineering Severe Accident Analysis Structural Integrity
Other Related Documentation	-

Scope of Work

ONR considers that the Requesting Party (RP) for the UK HPR1000 should present an adequate safety case regarding the potential detrimental effects of debris on the Safety Injection System (RIS [SIS]) and Containment Heat Removal System (EHR [CHRS]) during accident conditions. 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 as low as reasonably practicable (ALARP).

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.

RP also realises of the detrimental effect of debris and considers that it is necessary to take the debris effects into account when designing the RIS [SIS] and EHR [CHRS] systems and the relevant

filtration system. In the UK HPR1000 design, the In-containment Refuelling Water Storage Tank (IRWST) supplies borated water to the RIS [SIS] and EHR [CHRS] during design basis and design extension conditions (DEC). In a high energy pipe failure event, debris generated from the strainer upstream material (e.g. insulation material, coating and etc.) as a result of jet impingement and latent debris (i.e. pre-existing debris) could transport to the IRWST sump. Such debris has the potential to impair short and long term heat removal through the blockage of the strainers, degradation of heat transfer in the reactor core or the reactor pit and damage of the strainer downstream equipment (e.g. related pumps, valves and etc.).

In addition, RP thinks that the insulation configuration within the containment may be the most significant factor that affects the debris amount and some analysis has already been carried out. RP has already submitted < *ALARP analysis for insulation material selection in primary loop* > to ONR in July 2019, which concludes that RMI is the ALARP option for major components of the primary circuit. RP also plans to carry out a further analysis and perform an optioneering for the upstream material (e.g. insulation material) within the containment.

This resolution plan is provided as a response to ONR's expectation on this topic. It describes the current plan to address RO-UKHPR1000-0027 and contains the planned activities and expected submission reports for the demonstration of this topic.

Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
DBC	Design Basis Condition
DEC	Design Extension Condition
EHR	Containment Heat Removal System
GDA	Generic Design Assessment
HVAC	Heating, Ventilation and Air Conditioning

IRWST	In-containment Refuelling Water Storage Tank
ONR	Office for Nuclear Regulation (UK)
RIS	Safety Injection System
RMI	Reflective Metallic Insulation
RO	Regulatory Observation
RP	Requesting Party
SSCs	Structures, Systems and Components
UK HPR1000	UK Version of the Hua-long Pressurised Reactor

Deliverable Description

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

The Regulatory Observation (RO) Action 1 states that:

In response to this Regulatory Observation Action, RP 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 Plan Action 1

In response to this regulatory observation action, RP plans to carry out the investigation work on the

relevant good practice relating to the debris impact and submit a report < *The investigation report on the debris effect* > in April, 2020.

The review will mainly include the following contents:

- Investigation on regulatory requirements, guidance and other publications;
- Investigation on the upstream material selection (e.g. RMI insulation material and cable wrapping material in UK and around the world);
- Investigation on filtration technology in PWRs around the world;
- Investigation on sump strainer related tests, including the processes and findings

The documents or information RP plans to investigate include but not limit to:

[1] NEI 04-07. Pressurized Water Reactor Sump Performance Evaluation Methodology, Version 0, December 2004.

[2] OECD, Debris Impact on Emergency Coolant Recirculation, February 2004.

[3] NUREG/CR-6808, Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance, February 2003.

[4] 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, August 2017.

[5] NRC Public Meeting to Discuss Industry Sump Evaluation Methodology, March 2004.

[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, March 2012.

[7] NUREG/CR-6988. Final Report — Evaluation of Chemical Effects Phenomena in Post-LOCA Coolant, March 2009.

[8] NUREG/CR-6772. GSI-191: Separate-Effects Characterization of Debris Transport in

Water, August 2002.

[9] NUREG/CR-6874 GSI-191: Experimental Studies of Loss-of-Coolant-Accident-Generated Debris Accumulation and Head Loss with Emphasis on the Effects of Calcium Silicate Insulation, May 2005.

Through the investigation, RP plans to identify the possible difference between the current upstream material selection in UK HPR1000 and the RGPs. At the same time, RP plans to summarise a recommended upstream material selection in the containment in the conclusion of the < *The investigation report on the debris effect* >.

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

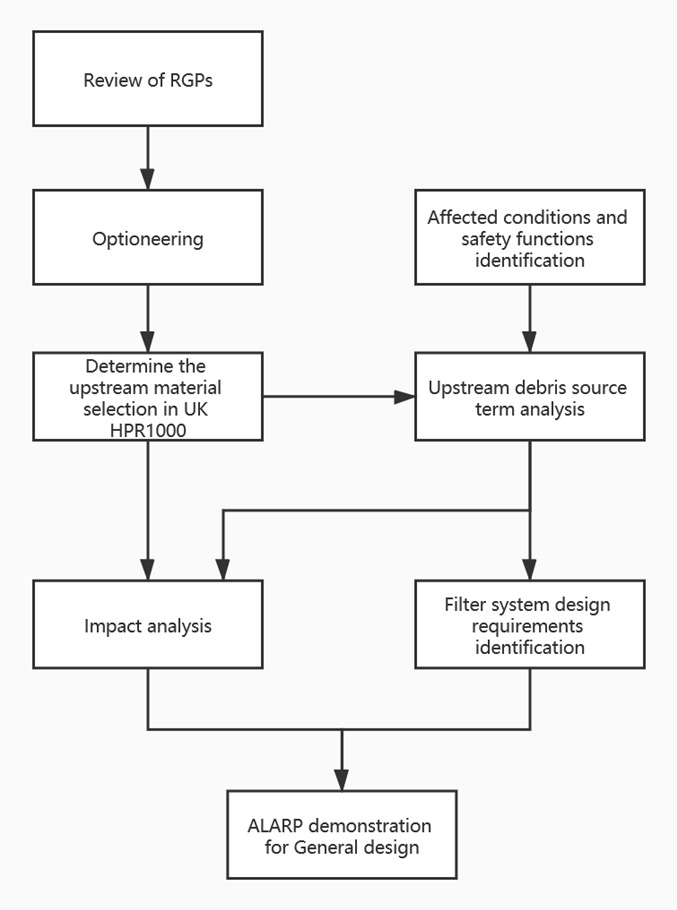
The RO Action 2 states that:

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

- *All accident conditions in which a demand on the RIS [SIS] or EHR [CHRS] is made, and identify limiting scenarios.*
- *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 Plan Action 2

Based on the outcome of the A1, RP plans to carry out a series of works including the optioneering, the impact analysis on the possible change of upstream material and the analysis related to debris. The overall scheme for this RO is presented as follows:



a) Review of RGPs

RP plans to carry out a review of RGPs. The detailed information is shown in the response of A1. Though the review, RP will identify the difference between the current upstream material selection in UK HPR1000 and RGP. Meanwhile, RP will summarise a recommended upstream material selection, such as selecting RMI as the insulation material inside the containment.

b) Optioneering on the upstream material

Considering the factors related to the debris effect, such as the nuclear safety (e.g. if RMI is adopted,

the debris source term will be expected to reduce effectively), impact on strainer tests, personnel health protection, cost, decommissioning etc., RP plans to carry out an optioneering to preliminarily determine the upstream material selection related to the debris inside the containment. The optioneering analysis process and result will be presented in < *Optioneering report of the upstream material* >, which will be submitted in May 2020. Meanwhile, the preliminary optioneering result will be the input of the upstream debris source term analysis in UK HPR1000.

c) Impact analysis

According to the optioneering result, the upstream material may change comparing with the current design in UK HPR1000. RP plans to carry out the impact analysis due to the possible change, which includes the impact on the upstream debris source term, HVAC, layout, mechanics and etc. The related analysis will be presented in < *Upstream material change impact* analysis *report* >, which will be submitted in July 2020.

d) Accident conditions and safety functions identification

RP plans to identify the safety functions which may be impacted by the debris in the IRWST. Meanwhile, the affected accident conditions and the limiting scenarios, using the relevant safety functions, will be identified

The relevant accident conditions and safety functions will be presented in < *Assessment of debris in IRWST to accident conditions* >, which will be submitted in May 2020.

e) Upstream debris source term analysis

RP plans to preliminarily analyse the upstream debris source term based on the optioneering result to further demonstrate that the changed upstream debris source term will have been optimised. The relevant information will be presented in the < *Strainer upstream debris source term analysis report* >, which will be submitted in July 2020.

f) Filter system design requirements identification

Based on the preliminary analysis of upstream debris source term in UK HPR1000, the preliminary filter system design requirements will be identified and presented in < *RIS-Safety Injection System Design Manual Chapter 4 System and Component Design* >.

g) ALARP demonstration for general design

RP plans to carry out the ALARP demonstration for general design based on the works mentioned above. Through the ALARP demonstration, RP plans to make recommendations for design changes if needed and demonstrate preliminarily that the residual risks associated with debris effects are reduced ALARP in this stage. Meanwhile, whether the filter system design requirements are achievable will be discussed in the ALARP demonstration. At last, an action plan will be made for the work that may need to be implemented at site licensing phase to further demonstrate that the risks related to debris have been reduced ALARP, such as filter system detailed design, filter system relevant tests and etc. The ALARP demonstration for this issue will be presented in < *ALARP Demonstration Report for Safety Systems* > in December 2020.

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

The RO Action 3 states that:

In response to this Regulatory Observation Action RP should develop a suitable and sufficient safety case regarding debris effects on the RIS [SIS] 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 UK HPR1000 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 Plan Action 3

In response to this Regulatory Observation Action, the detailed RP work plan is shown in the response of A2 and is summarised as follows:

Firstly, RP will carry out the review of RGPs;

Secondly, considering the related factors (nuclear safety, cost, etc), RP will carry out the optioneering to determine the preliminary upstream material selection in UKHPR1000.

Thirdly, based on the result of optioneering, RP will carry out the upstream material change impact analysis and debris related analysis (e.g. upstream debris source term analysis) to demonstrate whether the impact of changing upstream material is acceptable.

Fourthly, based on the works mentioned above, RP plans to preliminarily carry out the ALARP demonstration for this issue in GDA stage.

Meanwhile, there is no specific supplier for the sump strainer in GDA stage. The detailed filter system design, some related tests and analysis works required will be identified when the works mentioned above is finished.

Impact on the GDA Submissions

RP plans to submit the following reports (the report title may change according to the later work):

No.	Name	Time	Content
1	The investigation report on the debris effect	30th April 2020	Investigation on RGPs related to the debris effect.
2	Optioneering report of the upstream material	31st May 2020	Determine the preliminary upstream material related to the debris in UK HPR1000.
3	Assessment of debris in IRWST to accident conditions	31st May 2020	The identification of affected safety functions and accident conditions.
4	Upstream material change impact analysis report	31st July 2020	The impact analysis on the HVAC, layout, mechanics and etc. due to the upstream material changes.
5	Strainer upstream Debris Source Term analysis report	31st July 2020	The preliminary debris analysis in UK HPR1000 based on the optioneering.
6	ALARP Demonstration Report for Safety Systems	31st December 2020	Demonstration that the risks associated with debris effects have been reduced ALARP.

Timetable and Milestone Programme Leading to the Deliverables

See attached Gantt Chart in APPENDIX A.

Reference

1. CGN, GDA-REC-CGN-002391 - Pre Construction Safety Report - Chapter 7 Supporting Reference -RIS Safety Injection System Design Manual - Chapter4 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 [redacted]
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

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APPENDIX A RO-UKHPR1000-0023 Gantt Chart

Task and Schedule	2020												2021				
	31 Jan	29 Feb	31 Mar	30 Apr	31 May	30 Jun	31 Jul	31 Aug	30 Sep	31 Oct	30 Nov	31 Dec	31 Jan	28 Feb	31 Mar	30 Apr	31 May
RO Action 1																	
Development of <The investigation report on the debris effect>																	
Submission of <The investigation report on the debris effect>																	
RO Action 2																	
Development of <Optioneering report of the upstream material>																	
Submission of <Optioneering report of the upstream material>																	
Development of <Assessment of debris in IRWST under accident conditions>																	
Submission of <Assessment of debris in IRWST under accident conditions>																	
Development of <Upstream material change impact analysis report>																	
Submission of <Upstream material change impact analysis report>																	
Development of <Strainer upstream Debris Source Term analysis report>																	
Submission of <Strainer upstream Debris Source Term analysis report>																	
RO Action 3																	
Development of <ALARP Demonstration Report for Safety Systems>																	
Submission of <ALARP Demonstration Report for Safety Systems>																	
Assessment																	
Regulatory Assessment																	
Target RO Close Date																	