REGULATORY OBSERVATION Resolution Plan	
RO Unique No.:	RO-UKHPR1000-0032
RO Title:	Inadvertent Flooding of the Reactor Pit
Technical Area(s)	Fault Studies
Revision:	0
Overall RO Closure Date (Planned):	31/03/2021
Linked RQ(s)	RQ-UKHPR1000-0168 RQ-UKHPR1000-0224 RQ-UKHPR1000-0232 RQ-UKHPR1000-0307 RQ-UKHPR1000-0410
Linked RO(s)	
Related Technical Area(s)	3. Control & Instrumentation 11. Human Factors 14. Mechanical Engineering 15. Probabilistic Safety Analysis 19. Severe Accident Analysis 20. Structural Integrity
Other Related Documentation	
Scope of Work	

Background and Regulator's Expectations

The Requesting Party (RP) has submitted a number of documents for safety case and Regulatory Queries responses [1 to 5] about inadvertent flooding of the reactor pit for UK HPR1000. These submissions include fault identification, prevention, protection and mitigation measures, systems, structures and components (SSCs), and PSA analysis etc.

But the safety case submissions are incomplete and inconsistent regarding the risks posed by inadvertent flooding of the reactor pit.

ONR therefore raised RO-UKHPR1000-0032 to highlight these issues mentioned above.

ONR expects that the requesting party delivers a suitable and sufficient safety case to demonstrate that the risks associated with inadvertent flooding of the reactor pit during normal operations are *reduced to ALARP.*

It is important to note that the RP should choose its approach to making such a safety case, given there are different ways in which the objectives above can be achieved. The RP may wish to demonstrate that:

- *the RPV can tolerate the consequences of the identified fault sequences to a high degree of confidence; or*
- *the RP may wish to demonstrate that the UK HPR1000 design is sufficient to prevent, protect against or mitigate fault sequences that can lead to challenging the integrity of the RPV; or*
- *a combination of the above arguments.*

ONR considers that the following aspects should be considered by the RP in producing their safety case, as appropriate:

- *Fault identification – the requesting party should systematically identify all Postulated Initiating Events (PIEs) related to inadvertent flooding of the reactor pit, including those from spurious C&I and common cause failures. The RP should apply its methodology for identification of PIEs and the bounding and grouping process as appropriate.*
- *Fault frequency – the fault frequency should be determined, and a justification for the frequency should be provided. The justification should not solely rely on the current PSA models.*
- *Assessment of consequences – consequential failure of the RPV and other equipment due to the initiating events identified should be considered. The level of detail required in the RPs assessment of consequential failure should depend on the approach to its safety case.*
- *Identification of protection, prevention and mitigation – all safety functions and the corresponding SSCs (including human actions) credited in the prevention, protection or mitigation of faults identified should be identified and appropriately categorised and classified, respectively, using the RP's design principles. This should not be limited to the extant design, but should consider any further safety functions required.*
- *Deterministic demonstration of fault tolerance – the relevant design basis fault sequences should be identified and it should be demonstrated that adequate prevention, protection and mitigation exists to prevent identified challenge to the integrity of the RPV. The assessment should consider the expectations of SAPs FA.6 and FA.7 as appropriate.*
- *Identification of further risk prevention, protection or mitigation – the RP should consider whether the identified risks have been reduced to ALARP. In doing so, the RP should consider independence of levels of defence in depth, and the balance of risk between levels of defence in depth, ensuring that one safety measure does not adversely affect the reliability of*

another to operate when required.

- *Relevant updates to the PSA – The PSA should be updated to reflect the outcome of this work. The initiating event frequency for RPV rupture should include inadvertent reactor pit flooding if appropriate.*
- *Ultimately, ONR expects the RP to demonstrate that risks have been reduced to ALARP. This should be a multi-stranded argument including, as appropriate, deterministic and probabilistic arguments (FA.1).*

To achieve this, as part of the resolution of this RO, the RP will need to undertake the following activities:

- Provide a suitable and sufficient safety case related to inadvertent flooding of the reactor pit.
- Demonstration that the risks associated with inadvertent reactor pit flooding have been reduced to ALARP. This is a multi-stranded argument including, as appropriate, deterministic and probabilistic arguments.

This resolution plan provides the intended tasks, deliverables and schedule that will be undertaken to address the concerns raised by ONR regarding inadvertent reactor pit flooding.

Description of the Response and the Scope of Work

This resolution plan provides a response for the gap on inadvertent flooding of the reactor pit in the safety case, including:

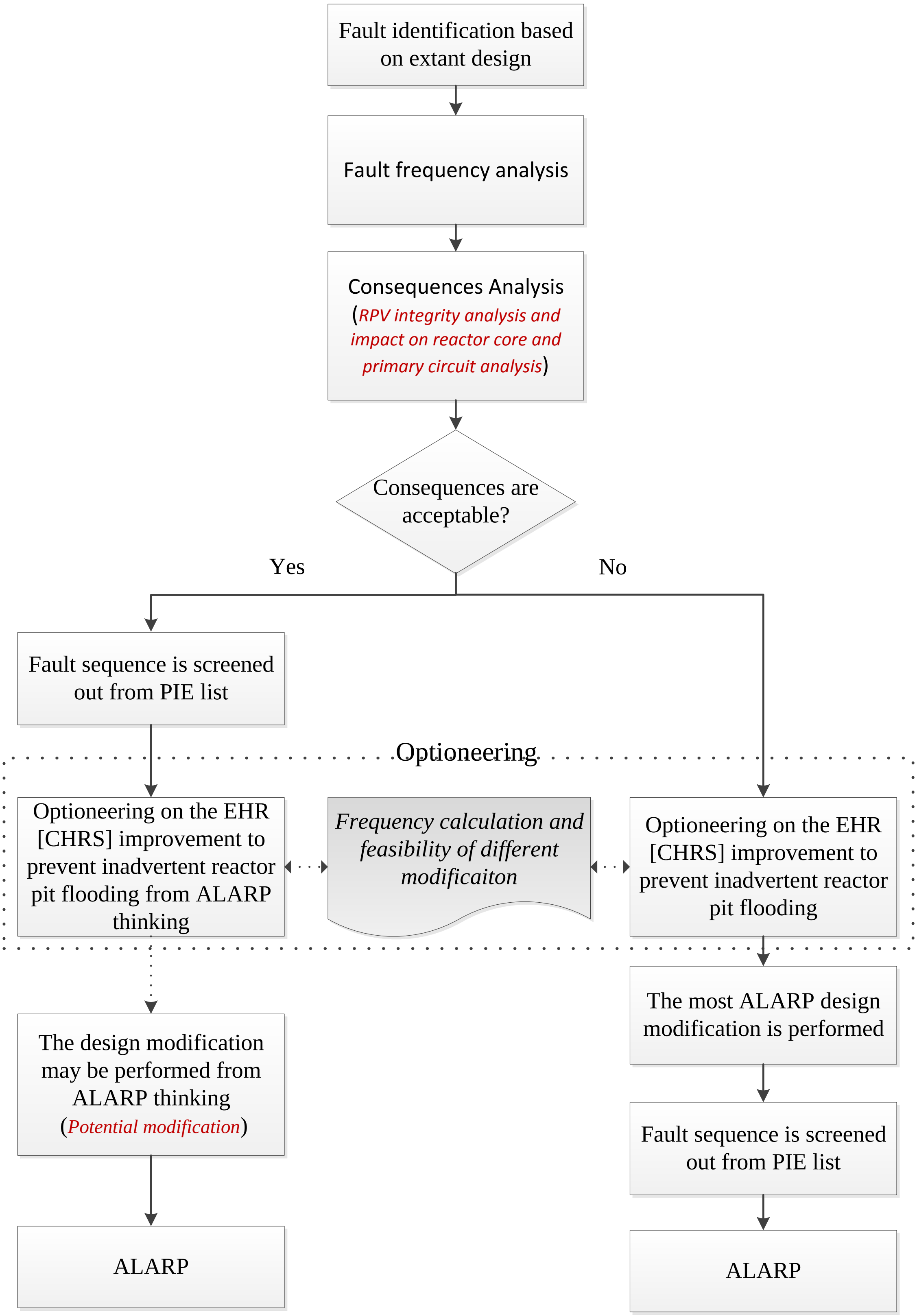
a) Providing a suitable and sufficient safety case related to inadvertent flooding of the reactor pit for the following key points:

- Fault identification – the RP will systematically identify all faults related to inadvertent flooding of the reactor pit, including those from spurious Instrumentation and Control (I&C) activation and common cause failures. The RP will apply its methodology for identification of PIEs as well as the bounding and grouping process as appropriate.
- Fault frequency determination and justification to support PIEs identification and ALARP analysis.
- Assessment of consequences to support PIEs identification and ALARP analysis.
- Using the prevention, protection and mitigation provided by SSCs against faults to present information around existing and any potential new identifications, modifications or demonstrations of effectiveness based on the optioneering analyses carried out.
- Justification that the risks associated with inadvertent reactor pit flooding have been

reduced to ALARP.

In HPR1000 (FCG3) design, it is justified that the integrity of the Reactor Pressure Vessel (RPV) is not affected by inadvertent flooding of the reactor pit using previous engineering experience of CGN's similar units. Therefore, the fault sequences of inadvertent flooding of the reactor pit are screened out based on the relatively low fault frequency and risk to the RPV integrity in the process of PIEs identification. In UK HPR1000 design, to be consistent with the UK context, the RP will perform the unmitigated consequence analysis and provide a sufficient safety case for inadvertent flooding of the reactor pit.

This resolution plan will be performed according to processes shown in the following figure.



Fault identification based on extant design
Fault frequency analysis
Consequences Analysis
(RPV integrity analysis and impact on reactor core and primary circuit analysis)
Consequences are acceptable?
Yes
No
Fault sequence is screened out from PIE list
Optioneering
Optioneering on the EHR [CHRS] improvement to prevent inadvertent reactor pit flooding from ALARP thinking
Frequency calculation and feasibility of different modificaiton
Optioneering on the EHR [CHRS] improvement to prevent inadvertent reactor pit flooding
The design modification may be performed from ALARP thinking
(Potential modification)
The most ALARP design modification is performed
Fault sequence is screened out from PIE list
ALARP
ALARP

Deliverable Description

RO-UKHPR1000-0032.A1 – Demonstate that the risks associated with inadvertent reactor pit flooding during normal operations are reduced to ALARP

The Regulatory Observation Action states that:

In response to this Regulatory Observation Action, GNS should:

- *Provide a suitable and sufficient safety case related to inadvertent flooding of the reactor pit.*
- *In responding to this Action the RP should consider the expectations and relevant guidance described in the RO, and ultimately provide a justification that the risks associated with inadvertent reactor pit flooding have been reduced to ALARP.*

In response to the Regulatory Observation, related works are planned as follows:

For this action, the RP's planned response consists of the following steps:

1) Fault identification

Based on the engineering experience of Yangjiang 5 and 6 units, there is no challenge to the structural integrity of the RPV, so the inadvertent reactor pit flooding by In-Vessel Retention (IVR) was screened out of the PIE identification. But for UK HPR1000, detailed evidence will be further provided. The following analyses including frequency analysis and consequences assessment will be carried out to determine whether it is a PIE that should be further considered in the design.

2) Fault frequency determination and justification

In order to support the PIEs identification and the optioneering process, a dedicated PSA model will be adequately developed to calculate the inadvertent reactor pit flooding frequency, and any SSCs or operator actions impacting these frequencies will be adequately analysed. The results of the fault frequency as well as the PSA analysis information will be provided in the report entitled *Optioneering on the EHR [CHRS] Related to the Inadvertent Reactor Pit Flooding* (Rev B, to be submitted in August 2020).

3) Assessment of consequences and PIEs identification

For the assessment of consequences of inadvertent flooding of the reactor pit, RP's planned response consists of carrying out impact analysis on the reactor core and primary circuit and RPV integrity analysis. Subsequently, the PIEs identification will be performed according to the results of the fault frequency and assessment of consequences.

a) Impact on reactor core and primary circuit analysis

The inadvertent flooding of the reactor pit during normal operation may result in the decrease of core inlet temperature and the increase of the reactor power. Some protection signals such as the high neutron flux may be triggered to limit the core power and protect the reactor. The assessment of this consequence will be evaluated in the report entitled *Impact on Reactor Core and Primary Circuit Analysis under the Inadvertent Flooding of the Reactor Pit Condition* (Rev A, to be submitted in July 2020). This assessment will include the analysis methodology, assumptions and conclusion for acceptability of the reactor core and primary circuit consequences.

b) RPV integrity analysis

For the inadvertent flooding of the reactor pit condition, the external surface of the RPV will be subject to thermal shock loading because of the cooling water injected, whilst maintaining a high internal pressure in RPV. The consequential failure model of RPV under this condition is fast fracture.

Considering the likely location of a defect occurring, as well as the loading and toughness of the material, a fast fracture analysis for the RPV core shell region (including weld) will be taken using an appropriate method to assess the failure risk of the RPV under inadvertent flooding of the reactor pit. A report entitled *The Thermal Shock Analysis of RPV while Inadvertent Flooding of Reactor Pit Condition* (Rev A, to be submitted in July 2020) will be issued to provide the results of fast fracture analysis. The input data, methodology, analysis process, and conclusion for acceptability of RPV integrity consequences will all be included in the report.

c) PIEs identification

Based on the fault frequency results, if the consequences are deemed acceptable (no risk to RPV integrity and reactor core and primary circuit), the faults related to inadvertent flooding of the reactor pit will be screened out directly and the related description will be provided in the updated version of *PIE list of UK HPR1000 of Internal Event (Except for Loss of Support System* (Rev E, to be submitted in August 2020). If there are significant consequences after the analysis, the faults will be treated as a PIE which will also be described in above document.

4) Prevention, protection or mitigation identification and demonstration

Identification and requirements of prevention/mitigation/protection will be explained in the report entitled *Optioneering on the EHR [CHRS] Related to the Inadvertent Reactor Pit Flooding* (Rev B, to be submitted in August 2020).

5) ALARP demonstration

In the ALARP demonstration, if the consequences are deemed acceptable (no risk to RPV integrity and reactor core and primary circuit), according to the UK context, the RP will carry out the optioneering process to further reduce the fault frequency and the risk of normal operation based on ALARP thinking. The design modification may be performed according to ALARP thinking.

On the other hand, if the consequences are deemed unacceptable (possibility of RPV integrity failure or impact on reactor core and primary circuit), the design modification will be necessary. The RP will perform ALARP optioneering, identify the ALARP solution and implement that modification in the design in order to prevent any unacceptable consequences identified.

In either case, whether the RP considers that the consequences acceptable or not, during the ALARP demonstration, a report entitled *Optioneering on the EHR [CHRS] Related to the Inadvertent Reactor Pit Flooding* (Rev B, to be submitted in August 2020) will provide the fault frequency of the modification design and possible alternative options, such as mechanical diversification, improve redundancy and so on. After optioneering, the justification of ALARP will be provided in the updated version of *ALARP Demonstration Report of Fault Studies* (Rev B, to be submitted in November 2020).

Finally, if the design modification is implemented, the design modification will be included in Design Reference 2.2 (DR 2.2). After DR 2.2 is released, relevant documents (such as Containment Heat Removal System (EHR [CHRS]) design manual and Impact Analysis on Internal Events Level 1 and Level 2 PSA etc.) will reflect DR 2.2 according to the design modification management procedure.

Impact on the GDA Submissions

The updated information will be incorporated into the following documents:

GDA Submission Document	Related ROAs	Planned schedule for submission
Impact on Reactor Core and Primary Circuit Analysis under the Inadvertent Flooding of the Reactor Pit Condition (Revision A)	ROA1	July 15th 2020
The Thermal Shock Analysis of RPV while Inadvertent Flooding of Reactor Pit Condition (Revision A)	ROA1	July 15th 2020
PIE list of UK HPR1000 of Internal Event (Except for Loss of Support System) (Revision E)	ROA1	August 14th 2020
Optioneering on the EHR [CHRS] Related to the Inadvertent Reactor Pit Flooding (Revision B)	ROA1	August 14th 2020
ALARP Demonstration Report of Fault Studies (Revision B)	ROA1	November 30th 2020

Timetable and Milestone Programme Leading to the Deliverables

See attached Gantt Chart in APPENDIX A.

Reference

[1] Response to RQ-UKHPR1000-0168. CM9 Ref. 2019/57315

[2] Response to RQ-UKHPR1000-0224. CM9 Ref. 2019/100762

[3] Response to RQ-UKHPR1000-0232. CM9 Ref. 2019/149084

[4] Response to RQ-UKHPR1000-0307. CM9 Ref. 2019/215308

[5] Response to RQ-UKHPR1000-0410. CM9 Ref. 2019/245542

APPENDIX A RO-UKHPR1000-0032 Gantt Chart

Tasks and Schedule	Steps	2020										2021			
		3	4	5	6	7	8	9	10	11	12	1	2	3	4
RO Action 1															
Impact on Reactor Core and Primary Circuit Analysis under the Inadvertent Flooding of the Reactor Pit Condition (Rev. A)	Development														
	Submission														
The Thermal Shock Analysis of RPV while Inadvertent Flooding of Reactor Pit Condition (Rev. A)	Development														
	Submission														
PIE list of UK HPR1000 of Internal Event (Except for Loss of Support System) (Rev. E)	Development														
	Submission														
Optioneering on the EHR [CHRS] Related to the Inadvertent Reactor Pit Flooding (Rev. B)	Development														
	Submission														
ALARP Demonstration Report of Fault Studies (Rev. B)	Development														
	Submission														
Assessment															
Regulators Assessment															
Target RO Closure Date															