REGULATORY OBSERVATION

REGULATOR TO COMPLETE

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Observation title:	Justification of the Structural Integrity Classification of the UK HPR1000 Main Steam Line and Associated Major Valves in the Safeguards Buildings
Lead technical topic: 20. Structural Integrity	**Related technical topic(s):** 2. Civil Engineering 9. Fault Studies 10. Fuel & Core 12. Internal Hazards 14. Mechanical Engineering 15. Probabilistic Safety Analysis 19. Severe Accident Analysis

Regulatory Observation

Background

ONR's safety assessment guidance expects that in accordance with UK health and safety law, risks are reduced So Far As Is Reasonably Practicable – (SFAIRP); for brevity, the term As Low As Reasonably Practicable (ALARP) will be used in this Regulatory Observation (RO) going forward. For the structural integrity (SI) discipline and other engineering disciplines, an important link between the engineering provision in a plant design and demonstration of safety, is the safety classification of Structures, Systems and Components (SSC).

ONR's SI assessment guidance (Refs.1 and 2) covers two situations:

1) The approach that should be followed for highest reliability structures and components, where the duty holder (or Requesting Party - RP) argues that gross failures can be discounted; and
2) The approach for other components and structures, where robust consequence arguments are expected when gross failure is not discounted.

In the Reference Design for the UK version of the Hua-long Pressurised Reactor (UK HPR1000), namely, Fangchenggang Unit 3 (FCG-3), Leak Before Break (LBB) arguments are applied to the Main Steam Line (MSL). This effectively precludes the need to consider the consequences of postulated gross failure, thus physical protection is not necessary for the MSLs for FCG-3. However, to meet ONR's expectations for the UK HPR1000, LBB should be dealt with as a secondary argument, providing defence-in-depth in the design and safety case. The UK HPR1000 RP has developed an approach to SI classification founded on a systematic consideration of the direct and indirect consequences of postulated gross failures (Ref. 3). The RP's approach allows for the identification of those structures and components that require a highest reliability claim. In the RP's SI classification scheme, highest reliability structures and components are referred to as High Integrity Components (HICs).

During Step 2 of the GDA for the UK HPR1000, the RP identified several SSCs, which in accordance with its SI classification approach, were considered as preliminary or ‘candidate HICs’. These ‘candidate HICs’ were subject to further assessment to determine whether, either through consequence analyse or design provision, it was reasonably practicable to avoid a HIC claim for the ‘HIC candidate’ structures and components of the UK HPR1000. During the ONR SI Step 3 assessment, potential shortfalls concerned with the demonstration of HIC classification for the UKHPR1000 Main Cooling Loop (MCL) components were identified, resulting in the issue of RO-UKHPR1000-0008 (Ref. 4).

Main Steam Line System and Components

The MSL was initially identified by the RP as being a ‘HIC candidate’, on the understanding that the final SI safety classification would be subject to the results from an analysis of the direct and indirect consequences of failure. This work was undertaken by the RP and used to produce the ‘Main Steam Line Component Safety Report’ (Ref. 5). In Ref. 5, the MSL is described as being “*….located at nuclear island and is divided into 3 trains. Each train of pipeline is connected with one SG steam nozzle. After passing through Steam Generator (SG) compartment, the main steam pipe is arranged to penetrate containment along reactor building annulus and enter the main steam valve station of Safeguard Building (BSX). Each train of steam lines are isolated zone by zone and are respectively located at 3 mutually independent valve stations. One steam valve station is located at Safeguard Building A* (BSA), while the other two are located at Safeguard Building B* (BSB) and are respectively located at both sides of Reactor Building (BRX).”*

(*Note – for clarification, future use of the term ‘Safeguards Buildings’ within this RO will refer to both BSA and BSB).

Ref. 5 also identifies the following key boundaries:

a) Boundaries with Steam Generator (SG): the weld to SG steam outlet nozzle;
b) Boundaries with Conventional Island (CI): the first weld outside BSX;

According to Ref. 5, the classification for the MSL is “…*founded on a systematic consideration of the direct and indirect failure consequences*…” which is “*based on the MSLs failure consequence analysis and potential design optioneering”.* As a result, “….*the MSLs inside the containment are classified as HIC and MSLs outside containment are classified SIC-2.”*

As part of the Step 4 SI assessment, ONR has sought clarification and finalisation of key SSC SI classifications, including the MSL. ONR has concluded that the RP has provided an adequate demonstration to show that it is not reasonably practicable to avoid a HIC classification of the MSL within the containment building (Ref. 6). The scope of this RO is therefore refers to the SI classification of the MSL sections and associated major valves within the Safeguard Buildings.

ONR’s preliminary review of the information provided to underpin the SI SIC-2 classification for the MSL outside containment (Refs. 7, 8, 9 and 10) concluded that there was insufficient information to demonstrate that a robust consequences analysis had been completed. The RP has since completed further consequence analyses and identified that the MSL will now be classified as HIC between the SG steam outlet nozzle weld and the first weld outside the BSX leading to the CI.

This is a significant change from the RP’s previous position and has prompted some uncertainty in relation to the reasoning and implementation of the RP’s approach to justify the SI classification of the MSL and major valves in the safeguard buildings. In addition, a corollary is that there would be a significant increase in the HIC boundary for the MSL, including HIC classified welds and subcomponents (including the Main Steam Isolations Valves - MSIVs). Based on the information received so far within the scope of the SI Step 4 assessment, there is a lack of robust information to justify the RP’s HIC SI classification for the MSL and associated major valves in the safeguard buildings. This RO is therefore raised to:

- Gain confidence in the RP’s approach and implementation of its methods and requirements for SI classification of the MSL and associated major valves in the safeguard buildings.
- Ensure that the SI classification of the MSL and associated major valves in the safeguard buildings is clearly defined, justified and aligned with the plant classification of SSCs and is commensurate with reducing relevant risks to ALARP.
- Ensure that the SI classification of the MSL has fully considered extant HIC claims and bounding/ranking methodologies already in place for the UK HPR1000.

- Clarify ONR's expectations for the structure and content of the MSL "structural integrity case", given the recent uncertainty and wider implications associated with assigning either a SIC-2 or HIC SI classification.

Relevant Legislation, Standards and Guidance

A key safety principle within the ONR Safety Assessment Principles (SAPs), and internationally, relates to achieving defence-in-depth for nuclear facilities. The expectations for defence-in-depth, which relate to International Atomic Energy Agency (IAEA) guidance, along with those for metallic structures and components are contained within the ONR SAPs (Ref. 1). The following SAPs, expanded in TAG NS-TAST-GD-016, *Integrity of Metal Components and Structures* (Ref. 2), are of particular relevance to this RO:

Engineering and Integrity of Metal Components and Structures Principles

EKP.3 Defence-in-depth

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.

ECS.2 Safety Classification of Structures, Systems and Components

Structures, systems and components that have to deliver safety functions should be identified and classified on the basis of those functions and their significance to safety.

ECS.3 Codes and Standards

Structures, systems and components that are important to safety should be designed, manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected to the appropriate codes and standards.

Highest reliability components and structures, paragraph 286

Discounting gross failure of a component or structure is an onerous approach to constructing an adequate safety case. Cases following this approach should provide an in-depth explanation of the measures over and above normal practice that support and justify the claim that gross failures can be discounted.

EMC. 1 Safety case and assessment

The safety case should be especially robust and the corresponding assessment suitably demanding, in order that a properly informed engineering judgement can be made that:

(a) the metal component or structure is as defect-free as possible; and

(b) the metal component or structure is tolerant of defects.

EMC. 2 Use of scientific and technical issues

The safety case and its assessment should include a comprehensive examination of relevant scientific and technical issues, taking account of precedent when available.

EMC.2 paragraph 293

Wherever possible, safety cases should not rely on claims of extremely high structural integrity.

EMC.3 Evidence

Evidence should be provided to demonstrate that the necessary level of integrity has been achieved for the most demanding situations identified in the safety case.

EMC.3 paragraph 295

To meet Principles EMC.1 and EMC.2, the safety case should include appropriate evidence of the following: (a) to (p).

Fault Analysis Principles

FA.3 Fault Sequences

Fault sequences should be developed from the initiating faults and their potential consequences analysed.

FA.5 Initiating Faults

The safety case should list all initiating faults that are included within the design basis analysis of the facility.

FA.5 paragraph 628

Initiating faults identified in Principle FA.2 should be considered for inclusion in this list, but the following need not be included:

(a)…
(b) failures of structures, systems or components for which appropriate specific arguments for preventing the initiating fault have been made (see, for example, Principle EMC.3).

Internal Hazard Principles
EHA.1 Identification and characterisation
An effective process should be applied to identify and characterise all external and internal hazards that could affect the safety of the facility.

EHA.3 Design basis events
For each internal or external hazard which cannot be excluded on the basis of either low frequency or insignificant consequence (see Principle EHA.19), a design basis event should be derived.

EHA.5 Design basis event operating states
Analysis of design basis events should assume the event occurs simultaneously with the facility's most adverse permitted operating state (see paragraph 631 c) and d)).

EHA.6 Analysis
The effects of internal and external hazards that could affect the safety of the facility should be analysed. The analysis should take into account hazard combinations, simultaneous effects, common cause failures, defence in depth and consequential effects.

EHA.7 Cliff-edge effects
A small change in design basis fault or event assumptions should not lead to a disproportionate increase in radiological consequences.

EHA.18 Beyond design basis events
Fault sequences initiated by internal and external hazards beyond the design basis should be analysed applying an appropriate combination of engineering, deterministic and probabilistic assessments.

Regulatory Expectations
In summary, ONR's expectations for the UK HPR1000 MSL and major valves within the Safeguards Building is that suitable justification is provided in the generic safety case regarding:

i) The implementation of adequate processes to establish the SI classification of the MSL within the Safeguards Buildings to inform the design of the UK HPR1000 to reduce the project and technical risks in a timely manner.
ii) Demonstration of appropriate consequence analyses (direct and indirect), along with design optioneering, taking cognisance of good practice to identify measures which may reduce risk.
iii) The consideration of measures to avoid "high levels" of structural integrity demonstration or to reduce risk (i.e. the provision of further defence-in-depth) where reasonably practicable.
iv) Demonstration that the structure and content of the "SI safety case" for the MSL is demonstrably proportionate to the SI classification, taking cognisance of the outcome of the design optioneering, and if appropriate, the implementation of reasonably practicable measures to reduce risks to ALARP.

The Regulatory Observatory Actions (ROAs) given below are structured in a way to enable provision of information by the RP in a logical manner, to inform ONR's assessment and the progression of Step 4 of GDA.

References
[1] Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0, ONR, November 2014
[2] ONR's Technical Assessment Guide (TAG): NS-TAST-GD-016 Revision 5, March 2017. Integrity of Metal Components and Structures. http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-016.pdf
[3] GHX30000002DOZJ03GN - Methods and Requirements of Structural Integrity Classification - Rev G - 23 December 2019 – CM 2019/378728
[4] RO-UKHPR1000-0008 - Justification of the Structural Integrity Classification of the Main Coolant Loop – 22 November 2020 - CM 2019/346343
[5] GHX44100007DNHX00GN - Main Steam Lines Component Safety Report - Rev B - 28 May 2020 – CM 2020/162007
[6] RQ-UKHPR1000-0970 - Structural Integrity - Main Steam Line Consequence Analyses and Structural Integrity Classification - Reactor Building - 21 July 2020 – CM 2020/219438
[7] RQ-UKHPR1000-0918 - Structural Integrity - Weld Ranking List for High Integrity Components - 30 June 2020 - CM 2020/196451

[8] RQ-UKHPR1000-0925 - Query relating to the hazards from the main steam line within the safeguard building - 3 July 2020 - CM 2020/156747
[9] RQ-HRP1000-1033 - Internal Hazards - IH Query on the High Energy Pipe Failure Assessment in the BSX - 17 August 2020 – CM 2020/241872
[10] RQ-UKHPR1000-0969 - Fault Studies - Main Steam Line SI Classification and Implications for Fault Analysis - 17 July 2020 – CM 2020/296991
[11] RO-UKHPR1000-0046 - Demonstration that the Risks to HIC Components from Internal Hazards are Reduced to ALARP – 11 September - CM 2020/271394

Regulatory Observation Actions

RO-UKHPR1000-0058.A1 – MSL Safeguard Buildings Consequence Analyses, Design Optioneering and Identification of Measures to Reduce Risk.

In response to this ROA, the RP should provide :

- Robust consequence analyses (direct and indirect) used to inform the SI classification of the MSL.
- ONR considers that the response to this action should include information on:
  - The scope of the consequence analyses (direct and indirect);
  - initiating event frequencies;
  - key assumptions; and
  - subsequent comparison with relevant design basis criteria.

ONR anticipates that exisiting or planned consequence analyses may provide useful information for the RP to address this action. However, the intent of this action is for the RP to demonstrate that the scope of the analyses is sufficient to inform the SI classification of sections of the MSL and associated major valves in the Safeguards Buildings.

Resolution required by: To be determined by the RP's Resolution Plan.

RO-UKHPR1000-0058.A2 – Justification that the Structural Integrity Classification of the MSL and Major Valves in the Safeguard Buildings is Commensurate with Reducing Risks ALARP.

In response to this ROA, and based on the responses to ROA 1, the RP should:

- Provide a demonstration that the SI classification of the MSL is commensurate with reducing risk ALARP, with a balanced consideration of the: benefits, detriments and application of gross disproportion i.e. ALARP optioneering.
- Provide a demonstration that an effective process for the SI classification has been implemented, including multi-discipline involvement, to ensure that all SSCs likely to be affected by, or with the potential to affect, the HIC MSL and that the necessary technical disciplines have been engaged and consulted in this process.
- ONR considers that the response to this action should include information on:
  - The implementation of the process for the SI classification of the MSL and associated major valves in the Safeguard Buildings.
  - The design optioneering to identify measures to limit the consequences (direct and indirect) of postulated gross failures to within the design basis, including world-wide OPEX e.g. piping restraints, blast/jetting diverter plates, building layout etc. so as to avoid a highest reliability claim for the MSL and associated major valves within the Safeguard Buildings.
  - A clear demonstration of how the disbenefits/burden of assigning a HIC classification to the MSL and associated major valves within the Safeguards Buildings has been coinsidered, and how factors such as through-life burden of avoidance of fracture demonstration and high quality inspection have been inlcuded in the comparison.
  - A demonstration that the SI classification of the MSL in the Safeguards Buildings is aligned to the UK HPR1000 plant classification of SSCs and if appropriate, that the relevant expectations of RO-UKHPR1000-0046 (Ref. 11) will be addressed.

Resolution required by: To be determined by the RP's Resolution Plan.

RO-UKHPR1000-0058.A3 – Demonstration of the Adequacy of the Structural Integrity Safety Case for the MSL and major valves within the Safeguards Building.

In response to this ROA, and based on the responses to ROAs 1-2, the RP should:

- Produce a strategy for providing an adequate "structural integrity safety case" for the entire length of the MSL and major valves within the Safeguards Buildings in a timely manner.

- ONR considers that the response to this action should include information on the:
    - Proposed “structural integrity case” and provisions to underpin any non-HIC structural integrity claims; and/or
    - Proposed “structural integrity case” and provisions to underpin a HIC structural integrity claim;
    - Demonstration that the consequences of failure of the NC classified section of the MSL outside of the Safeguards Buildings will not challenge the HIC clasification of the MSL or major valves within the Safeguards Buildings;
    - Provision for updating the fault analysis taking cognisance of the MSL SI classification; and
    - Provision for updating the hazard schedule(s) taking cognisance of the MSL SI classification.

Resolution required by: To be determined by the RP’s Resolution Plan.

REQUESTING PARTY TO COMPLETE	
Actual Acknowledgement date:	
RP stated Resolution Plan agreement date:	