REGULATORY OBSERVATION

REGULATOR TO COMPLETE

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Related RQ / RO No. and TRIM Ref: (if any)**:**	
Observation title:	Avoidance of Fracture Demonstration
Lead technical topic: 20. Structural Integrity	**Related technical topic(s):** 9. Fault Studies 11. Human Factors 12. Internal Hazards 13. Management of Safety Quality Assurance 14. Mechanical Engineering

Regulatory Observation

Background

ONR's assessment guidance [1] identifies expectations for structures and components where the RP or duty holder invokes highest reliability claims. In such situations the gross failure of these components is either deemed intolerable or analysis to demonstrate tolerance is difficult or uncertain. In these instances the case for discounting gross failure from the design basis is considered.

Discounting gross failure of a component or structure is an onerous approach to constructing an adequate safety case. The inferred likelihood of gross failure needs to be very low or the safety case claims gross failures can be discounted. 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.

In most cases where failure is discounted from the design basis it means no physical defence in depth can be introduced to eliminate, mitigate or protect against the consequences of failure. Instead, conceptual defence in depth is considered, with multiple robust safety case arguments expected. To achieve this aim, a key expectation informed by precedent in the United Kingdom (UK), relates to the integration of defect tolerance assessment, qualified inspection and conservative material properties. This is referred to as an "avoidance of fracture demonstration".

In GDA, ONR seeks a proportionate avoidance of fracture demonstration with appropriately conservative assumptions. This should include a consideration of all the potential failure mechanisms of the component and the measures that have been taken to guard against them. Whilst design code compliance can provide a certain amount of assurance, there are certain areas which, typically, ONR expects to be further reinforced in the safety case, namely: fracture analyses, reliable and readily qualified manufacturing inspections, along with conservative and achievable material properties.

Noting the expectation to infer a reliability beyond that which can be claimed by design code compliance, care needs to be taken to achieve appropriate balances between the three principal inputs to the avoidance of fracture demonstration, namely: defect tolerance assessment (DTA), material property evaluation and inspection qualification. For example, excessive conservatism in DTA can result in unrealistic demands for inspection qualification or in material properties e.g. fracture toughness.

This is a challenging expectation for GDA Requesting Parties (RPs) and requires the exercise of sound judgements, the development of integrated approaches and adequate arrangements for reconciliation within the structural integrity discipline.

In GDA Step 2, it was noted that the RP is developing an understanding of the expectations for the avoidance of fracture demonstration for UK HPR1000. However, ONR was not fully convinced that the RP understands the role and significance of the avoidance of fracture demonstration in underwriting the highest reliability claim for highest reliability structures and components (referred to a High Integrity Components (HICs) by the RP). One area that requires further development is the understanding of the integration of the fracture analyses, qualified inspection and material properties that will underwrite such cases [2].

This RO is therefore raised to:

- Address the gaps identified during ONR's Step 2 Structural Integrity assessment [1] and clearly articulate ONR's regulatory expectations;
- Ensure that the avoidance of fracture demonstration considers the holistic avoidance of fracture demonstration and does not impart unrealistic burdens on the individual factors for HIC (e.g. DTA, material properties and inspection activities) ;
- Gain confidence that the RP understands the conditions for use of avoidance of fracture demonstration and that the RP has satisfactory processes to strike the required balance on the contributing elements of the demonstration.

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Relevant Legislation, Standards and Guidance

A key safety principle within the ONR SAPs [1] and internationally, relates to achieving defence in depth. The expectations for defence in depth, which relate to International Atomic Energy Agency (IAEA guidance), along with those for metallic structures and components are therefore contained within the ONR SAPs [1]. The following SAPs and associated guidance, expanded in the technical assessment guide on the Integrity of Metal Components and Structures [3], are of particular relevance to this RO:

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.

Highest reliability components and structures
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) the use of sound design concepts and proven design features;

(b) a detailed design loading specification covering normal operation, faults and accident conditions. This should include plant transients and internal and external hazards;
(c) consideration of potential in-service degradation mechanisms;
(d) analysis of the potential failure modes for all conditions arising from design specification loadings;
(e) use of proven materials;
(f) confirmatory testing to demonstrate that the parent materials and welds have the appropriate material properties, especially strength and the necessary resistance to fracture;
(g) application of high standards of manufacture, including manufacturing inspection and examination;
(h) high standards of quality management throughout all stages of design, procurement, manufacture, installation and operation (see also paragraph 207 on excluding foreign material);
(i) pre-service and in-service examination to detect and characterise defects at a stage before they could develop to cause gross failure;
(j) defined limits of operation (operating rules), supported as necessary by safety measures (eg overpressure protection);

EMC.3 paragraph 296
The strength and extent of the evidence provided here should be commensurate with its importance to the overall safety case.

EMC.34 Defect sizes
Where high reliability is needed for components and structures and where otherwise appropriate, the sizes of crack-like defects of structural concern should be calculated using verified and validated fracture mechanics methods with verified application.

EMC.34 paragraph 317
The calculated crack sizes of concern should be compared with the results of the manufacturing, pre-service and in-service examinations.

Regulatory Expectations

In summary, ONR's expectations for the UK HRP1000 avoidance of fracture demonstration is that a suitable and sufficient justification is provided in the generic safety case regarding:

i) The requirements placed on each contributing element to the avoidance of fracture demonstration, taking cognisance of good practice, to identify measures which may reduce risk.
ii) The strengths and weaknesses of the contributing elements to the avoidance of fracture demonstration.
iii) The route and content of the avoidance of fracture demonstration.
iv) The development of adequate processes to resolve the potential conflicts between the contributing elements of the avoidance of fracture demonstration in a timely manner, to reduce risks for GDA.

It is not the expectation that specific DTAs are completed as part of the resolution of this RO. The focus should be on providing confidence that the role of the avoidance of fracture demonstration within the generic safety case is understood. In addition, the interplay between possibly contributing elements is clear.

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 the GDA.

References

[1] Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0, ONR, November 2014
[2] ONR-GDA-UKHPR1000-AP-18-018 Revision 0, GDA Step 2 Assessment of Structural Integrity of the UK HPR1000 Reactor, November 2018.
[3] ONR's Technical Assessment Guide (TAG): NS-TAST-GD-016 Integrity of Metal Components and Structures http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-016.pdf

Regulatory Observation Actions

RO-UKHPR1000-0006.A1 – Role and importance of the avoidance of fracture demonstration to the UK HPR1000 safety case

In response to this ROA, GNS should provide :

- an explanation of how the avoidance of fracture demonstraiton will be used within the generic safety case to support the claim that failure can be discounted from the design basis.
- a clear description of how the safety case is supported by the claims, arguments and evidence generated as part of the avoidance of fracture demonstration.
- ONR considers that the response to this Action should also include information on:
    - the location of the claim within the safety case;
    - the prominance this claim has within the safety case; and
    - the auditable trail between the claim, arguments and evidence.

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RO-UKHPR1000-0006.A2 -Identification of the contributing elements of the avoidance of fracture and their relationships

The RO action states that:

In response to this ROA, GNS *should provide:*

- the strategy for the creation of the avoidance of fracture demonstration, which will include an explicit explanation of the interrelationships between the contributing elements.
- the reconciliation strategy the RP will develop and implement to justify the adequacy of the avoidance of fracture justification. This should include, but not be limited to:
    - Confirmation that appropriate conservatisms are being used in each input (e.g. defect tolerance assessment, inspection qualification or material property assumptions) to the avoidance of fracture justification.
    - The process for the resolution of conflicts between the contributing elements of the avoidance of fracture justification.
- ONR considers that the response to this Action should include information on:
    - The documented strategy for creating the avoidance of fracture demonstrations, associated processes and approach, which provide information on the objectives, scope and purpose for the overall UK HPR1000 safety case and how this will be cascaded into individual documents.
    - Examples of the reconciliation process.

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RO-UKHPR1000-0006.A3 – Justification of the inputs used in the defect tolerance assesments

In response to this ROA, GNS should provide:

- the generic inputs to be used within the proposed defect tolerance assessments. This should include, but not be limited to, a clear description of the source of the inputs, its veracity and why the inputs are consistent with the level of reliabilty being sought in the avoidance of fracture demonstration.
- ONR considers that the response to this Action should include, but not be limited to, information on:
    - Limiting design transients and loads;
    - Operation loading profile and combination of transients;
    - Material properties (including the impact of degradation mechanisms);
    - Defect locations and geometries.

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REQUESTING PARTY TO COMPLETE

Actual Acknowledgement date:	
RP stated Resolution Plan agreement date:	