CGN EDF General Nuclear System	REGULATORY OBSERVATION RESOLUTION PLAN RO-UKHPR1000-0006	Rev.: 1	Page: **1** / **12**
		GDA-REC-GNSL-005810	

REGULATORY OBSERVATION Resolution Plan	
RO Unique No.:	RO-UKHPR1000-0006
RO Title:	Avoidance of Fracture Demonstration
Technical Area(s)	Structural Integrity
Revision:	Rev 1
Overall RO Closure Date (Planned):	2021-04-30
Linked RQ(s)	RQ-UKHPR1000-0057/RQ-UKHPR1000-0058/RQ-UKHPR1000-0059/ RQ-UKHPR1000-0082/RQ-UKHPR1000-0110/RQ-UKHPR1000-0113/ RQ-UKHPR1000-0145/RQ-UKHPR1000-0452
Linked RO(s)	-
Related Technical Area(s)	9. Fault Studies 11. Human Factors 12. Internal Hazards 13. Management of Safety Quality Assurance 14. Mechanical Engineering
Other Related Documentation	-

Scope of Work

Background

ONR's structural integrity discipline covers the engineering assessment of the integrity of metallic components and structures. The ONR has specific expectations if the consequences of postulated gross failure are discounted. In these situations the ONR expects a highest reliability claim. For UK HPR1000, this class of structures and components is termed as High Integrity Component (HIC). For HIC it needs to be inferred that the likelihood of gross failure is extremely low or that gross failure can be discounted.

However, the structural integrity demonstration for HIC structures and components is an onerous route to constructing an adequate safety case, with an in-depth explanation of the measures over and above normal practice expected to justify the claim that gross failure can be discounted. In order to achieve this goal, and taking cognisance of existing good practice, along with the approaches adopted in previous GDA projects, an avoidance of fracture demonstration is expected for HIC structures and components. The aim is to demonstrate that the component enters service without structural defects of concern and that the structure or component is tolerant of defects during life with an appropriate margin.

For UK HPR1000, the claim of avoidance of fracture demonstration has been presented in the submitted Chapter 17 Structural Integrity (SI) of Pre-Construction Safety Report (PCSR) V0 (Ref. 1), and along with a series of reference documents covering the key elements of the case and relevant methodologies:

- *Safety Case Methodology for HIC and SIC Components* (Ref. 2),
- *Method and Requirements of Structural Integrity Classification* (Ref. 3),
- *Equipment Structural Integrity Classification List* (Ref. 4),
- *Weld Ranking Procedure* (Ref. 5),
- *Application of Weld Ranking Procedure* (Ref. 6),
- *Defect Tolerance Assessment methodology for HIC Components* (Ref. 7),
- *System and Components loadings for Defect Tolerance Assessment* (Ref. 8),
- *Strategy and Plan of Non-Destructive Testing for High Integrity Component* (Ref. 9),
- *Inspection Qualification Strategy for High Integrity Components* (Ref. 10).

At the beginning of Step 3, RO-UKHPR1000-0006 (Avoidance of fracture demonstration) was raised by ONR in response to specific gaps in the generic safety case, identified during their Step 2 assessment. One of the main purposes of the RO is to provide advice and guidance to the RP on ONR's expectations regarding the provision of a suitable and sufficient justification of the approach, clarification of the route to the arguments and evidence and by outlining the specific expectations for each of the contributing elements (or key inputs) in the avoidance of fracture demonstration. A final aim of the RO was to highlight to the RP the importance of developing processes to integrate the fracture analyses, qualified inspection and material properties in underwriting the avoidance of fracture demonstration for HIC.

In order to address RO-UKHPR1000-0006 and to achieve ONR's expectations, this resolution plan is developed to outline the programme of work for the avoidance of fracture demonstration for HIC structures and components in UK HPR1000. The work to address each action of the RO is detailed below.

Abbreviations and Acronyms

CAE	Claim-Argument-Evidence
DSM	Defect Size Margin
DTA	Defect Tolerance Assessment
GNS	General Nuclear System Limited
HIC	High Integrity Component
NDT	Non-Destructive Testing
ONR	Office for Nuclear Regulation

PCSR	Pre-Construction Safety Report
RO	Regulatory Observation
RP	Requesting Party
SI	Structural Integrity
SIC	Structural Integrity Class
SSCs	Structures, Systems and Components
UK HPR1000	The UK Version of the Hua-long Pressurized Reactor
UK	United Kingdom of Great Britain and Northern Ireland

Scope of work

In accordance with the regulatory observation actions of RO-UKHPR1000-0006, the scope of work in this resolution plan covers three aspects:

1) the role and importance of the avoidance of fracture demonstration to the UK HPR1000 safety case.
2) identification of the contributing elements of the avoidance of fracture and a development of a process for the reconciliation of these elements.
3) justification of the inputs used in the defect tolerance assessments.

On the basis of the documentation submitted prior to Step 3 and the planned step 3 and step 4 submissions, and taking cognisance of the regulatory expectations, the following documents will be updated or produced to address this RO and achieve ONR's regulatory expectations.

1) ***PCSR Structural Integrity Chapter 17 V1***
2) ***Safety Case Methodology for HIC and SIC Components***
3) ***Avoidance of Fracture Reconciliation Strategy***
4) ***Avoidance of Fracture Reconciliation for RPV Flange-nozzle Shell to Core Shell Weld***
5) ***Avoidance of Fracture Reconciliation for RPV Inlet Nozzle to Safe End Weld***
6) ***GDA technical justification for RPV Flange-nozzle Shell to Core Shell Weld***
7) ***GDA technical justification for RPV Inlet Nozzle to Safe End Weld***
8) ***Defect Tolerance Assessment of RPV Core Shell to Transition Ring Weld***
9) ***Defect Tolerance Assessment of Flange-nozzle Shell to Core Shell Weld***
10) ***Defect Tolerance Assessment of RPV Inlet Nozzle to Safe End Weld***

This Resolution Plan describes the current plan to address RO-UKHPR1000-0006. However, as the work develops, it may be necessary to adjust or update this plan to align with the latest review schedule in agreement with the regulators.

Deliverable Description

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

The RO action 1 states that:

In response to this ROA, GNS should provide :

- *an explanation of how the avoidance of fracture demonstration 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 prominence this claim has within the safety case; and*
  - *the auditable trail between the claim, arguments and evidence.*

Resolution Plan

For Action 1, the submitted PCSR chapter 17 V0 has relevant information for HIC components, with the avoidance of fracture demonstration referenced in sub-claim 2. In addition, the relevant main contributing elements, such as Defect Tolerance Assessment (DTA), high reliability NDT and material properties, and the basic relationships among them are also described in sub-chapter 17.6.1.2.

However, the RP acknowledges that there are still some gaps between the delivered submissions and regulatory expectations, e.g. absence of clear description of the evidence to support the avoidance of fracture demonstration and which specific safety cases will be developed to support this sub-claim in format of arguments and evidence.

Therefore, the RP will update the ***Pre-Construction Safety Report Chapter 17 Structural Integrity*** (Rev.V1) to respond to this action.

This document will be updated by 10th January 2020 to reinforce the relevant contents of the avoidance of fracture demonstration. The main aspects are:

- revise the chapter route map of structural integrity to highlight the location of avoidance of fracture demonstration within the safety case.
- more clearly describe arguments and evidence of avoidance of fracture demonstration, and specify which safety cases will be or have been generated to support this sub-claim in format of arguments

and evidence.

Meanwhile, for the ***Safety Case Methodology for HIC and SIC Components*** (Rev.C), the objective of this document is to guide the designer to develop Component Safety Reports to demonstrate structural integrity of SSCs, which cover HIC and SIC-1/SIC-2/SIC-3 components. The Revision C of this document will be updated to reflect the expectations from ONR by 30th April 2019. The main aspects are:

- revise the chapter 3.1 and Appendix A to present the logical relationship between structural integrity classification and safety cases.
- revise the Appendix C 'Avoidance of Fracture' to detail the role of avoidance of fracture demonstration, main contributing elements and the logical relationship with structural integrity demonstration of HIC component.
- revise the Chapter 4 and Appendix B to more clearly present arguments and evidence of avoidance of fracture demonstration, and highlight the location of avoidance of fracture demonstration in the chapter route map of structural integrity.
- using the identified arguments and evidence, the logical relationship flowchart of safety cases to support the avoidance of fracture demonstration will be developed in the format of claims, arguments and evidence (CAE). The main safety case documentation to underpin the main inputs include:

  General:

  - *Component Safety Reports of HIC Components*
  - *Method and Requirements of Structural Integrity Classification*
  - *Equipment Structural Integrity Classification List*
  - *Weld Ranking Procedure*
  - *Application of Weld Ranking Procedure*
  - *Avoidance of Fracture Reconciliation Strategy*
  - *Avoidance of Fracture Reconciliation Process between Contributing Elements*

  Contributing element 1: (Defect Tolerance Assessment (DTA) related documentation)

  - *Defect Tolerance Assessment Methodology for HIC Components*
  - *System and Components Loadings for Defect Tolerance Assessment*
  - *Defect Tolerance Assessment Reports of Limiting Locations*

  Contributing element 2: (High Reliability NDT related documentation)

- *Inspection Qualification Strategy for High Integrity Components*
- *Access and Inspectability Assessment*
- *Re-grouping Application of Weld Ranking Procedure*
- *NDT Inspection Specifications of Limiting Locations*
- *GDA Technical Justifications of Limiting Locations*

Contributing element 3: (Material Property related documentation)

- *Supplementary Toughness Test Requirements of Materials for HIC Components*

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.*

Resolution Plan

In the avoidance of fracture demonstration, three contributing elements (DTA, High Reliability NDT, and Material Property) are inter-related and their interaction is shown in Figure 1. In the UK HPR1000 GDA, DTA and high reliability NDT (GDA TJ) are normally carried out in parallel. For the DTA, conservative material properties are taken from codes and direct testing of material properties (fracture toughness) are reserved for the licensing stage of the project i.e. post GDA. Adequate margin is normally demonstrated through a reconciliation process where the inputs (namely DTA results, capability of GDA TJ and material properties) are

compared.

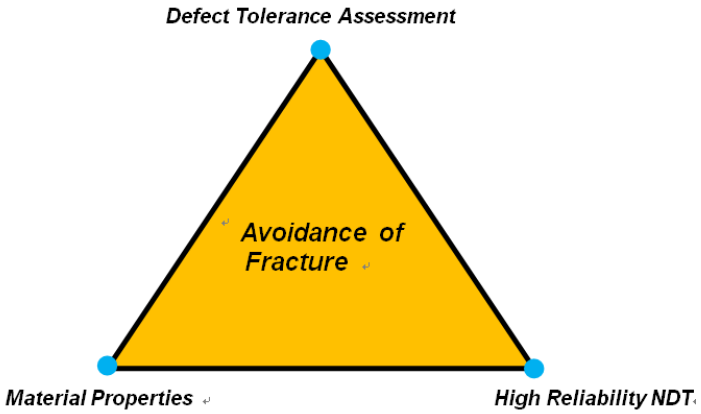

Figure 1 Inter-relationship of contributing elements

The RP has issued ***Safety Case Methodology for HIC and SIC Component*** (Rev C) in RO-UKHPR1000-0006.A1 to provide preliminary information relating to the contents and inter-relationships between the elements mentioned above. Furthermore, an outline of the reconciliation process to resolve potential conflicts between these elements was presented in ***Pre-Construction Safety Report Chapter 17 Structural Integrity*** (Rev.V0) (Ref.1) as well.

However, the RP recognises that there are still some gaps between the delivered submissions and regulatory expectations, e.g. absence of clear explanation of the interrelationships between the contributing elements, and associated route or approach to reconciliation for the avoidance of fracture demonstrations.

The RP will therefore issue the ***Avoidance of Fracture Reconciliation Strategy*** (Rev.A) by 31st October 2019, which specifies a reconciliation strategy in the avoidance of fracture demonstration when conflicts between the DTA and GDA TJ exist. This strategy aims to ensure an adequate safety margin whilst maintaining sufficient conservatisms in the avoidance of fracture demonstration.

Meanwhile, the RP will give two examples whereby the reconciliation strategy is applied. The first example is reconciliation process for RPV Flange-nozzle Shell to Core Shell Weld, and the second example is reconciliation process for RPV Inlet Nozzle to Safe End Weld.

Consequently, the RP will issue the following documents for the first example:

A) ***Defect Tolerance Assessment of Flange-nozzle Shell to Core Shell Weld*** (Rev.A) by 30th July 2019

B) ***GDA Technical Justification for RPV Flange-nozzle Shell to Core Shell Weld*** (Rev.C) by 29th February 2020

C) ***Avoidance of Fracture Reconciliation for RPV Flange-nozzle Shell to Core Shell Weld*** (Rev.A) by 15st March 2020

The following documents for the second example:

A) ***Defect Tolerance Assessment of RPV Inlet Nozzle to Safe End Weld*** (Rev.A) by 31st January 2020

B) ***GDA Technical Justification for RPV Inlet Nozzle to Safe End Weld*** (Rev.A) by 31st March 2020

C) ***Avoidance of Fracture Reconciliation for RPV Inlet Nozzle to Safe End Weld*** (Rev.A) by 31th December 2020

In addition, the RP will update the ***Safety Case Methodology for HIC and SIC Components*** to Rev D by 20th November 2019 to confirm whether there is adequate information to demonstrate how to carry out avoidance of fracture demonstration in UK HPR1000 safety cases, taking cognisance of the latest understanding and progress of avoidance of fracture demonstration during Step 3. The main developments as follows:

- revise Appendix C to detail the objective and scope of avoidance of fracture demonstration, specific requirements on contributing elements and the interrelationships between the contributing elements.
- revise Chapter 4 and Appendix B to more clearly identify and detail the arguments and evidence to underpin the avoidance of fracture demonstration, and to specify how these arguments and evidence are contained in individual documents. This will be expressed through a logical relationship flowchart of safety cases in a CAE format.
- summarise the reconciliation strategy applied to resolve potential conflicts between the contributing elements of avoidance of fracture demonstration to be added to Appendix C using the current status of safety case and delivery plan.

RO-UKHPR1000-000N.A3 – Justification of the inputs used in the defect tolerance assessments

The RO action states that:

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 reliability 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.*

Resolution Plan

The generic inputs used in proposed DTA report covers defect locations, geometries, various types of loadings, material properties, etc.

The ***Systems and Components Loadings for Defect Tolerance Assessment*** (Ref. 8) covers the loadings

description, including permanent loads, transients loads, seismic loads, etc. Further detailed information, such as operation loading profile, will be stated in each DTA report. Moreover, these DTA reports will document the conservative assumptions used to enable proportionality with the level of reliability being sought in the avoidance of fracture demonstration. These DTA reports also will include the material properties, which include the impact of degradation mechanisms.

The defect locations are derived from ***Application of Weld Ranking Procedure*** (Ref. 6), and detailed description of defect locations and geometries will be illustrated in each DTA report. ***Defect Tolerance Assessment of RPV Core shell to Transition Ring Weld*** (Rev.A) will be issued by 30th June 2019, ***Defect Tolerance Assessment of Flange-nozzle Shell to Core Shell Weld*** (Rev.A) will be issued by 30th July 2019, and ***Defect Tolerance Assessment of RPV Inlet Nozzle to Safe End Weld*** (Rev.A) will be issued by 31st January 2020.

The development and updating of the four key documents outlined in the response to Actions 1, 2 and 3 together with the timescales to submit these documents are given in schedule at Appendix A. A period to allow ONR consideration of the technical reports and to close-out the RO is also included in the schedule.

Impact on the GDA Submissions

The PCSR Chapter 17 (Rev. V1) and the following supporting submission documents will be involved in this RO.

GDA Submission Document	Related ROAs	Planned schedule for submission
Pre-Construction Safety Report Chapter 17 Structural Integrity (Rev. V1)	ROA1	10th January 2020
Safety Case Methodology for HIC and SIC Components (Rev. C)	ROA1	30th April 2019
Avoidance of Fracture Reconciliation Strategy (Rev. A)	ROA2	31th October 2019
Defect Tolerance Assessment of Flange-Nozzle shell to Core Shell weld (Rev. A)	ROA2 and ROA3	30th July 2019
GDA Technical Justification for RPV Flange-nozzle Shell to Core Shell Weld (Rev. C)	ROA2	29th February 2020
Avoidance of Fracture Reconciliation for RPV Flange-nozzle Shell to Core Shell Weld (Rev. A)	ROA2	15th March 2020
Defect Tolerance Assessment of RPV Inlet Nozzle to Safe End Weld (Rev. A)	ROA2 and ROA3	31th January 2020
GDA Technical Justification for RPV Inlet Nozzle to Safe End Weld (Rev. A)	ROA2	31th March 2020

Avoidance of Fracture Reconciliation for RPV Inlet Nozzle to Safe End Weld (Rev. A)	ROA2	31th December 2020
Safety Case Methodology for HIC and SIC Components (Rev. D)	ROA2	20th November 2019
Defect Tolerance Assessment of RPV Core shell to Transition Ring Weld (Rev. A)	ROA3	30th June 2019

Timetable and Milestone Programme Leading to the Deliverables

See attached Gantt Chart in APPENDIX A.

Reference

[1] Pre-Construction Safety Report Chapter 17 Structural Integrity, GHX00620017KPGB02GN, Revision V0, Sep.2018.

[2] Safety Case Methodology for HIC and SIC Components, GHX00100001DPFJ44DS, Revision A, May. 2018.

[3] Method and Requirements of Structural Integrity Classification, GHX30000002DOZJ03GN, Revision E, May.2018.

[4] Equipment Structural Integrity Classification List, GHX30000003DOZJ03GN, Revision D, May. 2018.

[5] Weld Ranking Procedure, GHX00100004DPCH03GN, Revision F, May. 2019.

[6] Application of Weld Ranking Procedure, GHX00100005DPCH03GN, Revision D, May. 2019.

[7] Defect Tolerance Assessment Methodology for HIC Components, GHX00100066DPLX03GN, Revision C, Jun. 2018.

[8] System and Components Loadings for Defect Tolerance Assessment, GHX00100002DPLX44GN, Revision A, Sep. 2018.

[9] Strategy and Plan of Non-Destructive Testing for High Integrity Component, GHX00100107DPCH03GN, Revision D, Jul. 2018.

[10] Inspection Qualification Strategy for High Integrity Component, GHX00100028DPCH03GN, Revision C, Jul. 2018.

CGN EDF General Nuclear System	REGULATORY OBSERVATION RESOLUTION PLAN RO-UKHPR1000-0006	Rev.: 1	Page: 11 / 12
		GDA-REC-GNSL-005810	

PREVIOUS REVISIONS RECORD				
Rev.	**Author**	**Scope/Reason of Revision**	**Date**	**Page**
0	[redacted]	*The first revision*	*2019.4.16*	*11*

	Name	Company	Position	Signature	Date
Author	[redacted]	CGN	Designer of Material, Weld & NDT	[redacted]	2020.1.8
	[redacted]	CGN	Topic Area Lead of Structural Integrity	[redacted]	2020.1.9
	[redacted]	CGN	Designer of Equipment Mechanics	[redacted]	2020.1.9
Reviewer	[redacted]	CGN	Vice head of Material, Weld & NDT Branch	[redacted]	2020.1.9.
	[redacted]	CGN	Director Designer of Equipment Mechanics Analysis Branch	[redacted]	2020.01.09
	[redacted]	CGN	Chief Designer of NP department	[redacted]	2020.1.10.
	[redacted]	CGN	Project Deputy Chief Designer	[redacted]	2020.1.10
	[redacted]	CGN	Design Manager	[redacted]	2020.1.11
Approver	[redacted]	CGN	Chief Engineer of Project	[redacted]	2020.1.16

	Name	Company	Position	Signature	Date
Reviewer	[redacted]	General Nuclear System	Structural Integrity PC	[redacted]	27/01/2020
Approver	[redacted]	General Nuclear System	CTO	[redacted]	28/1/2020

CGN EDF General Nuclear System	REGULATORY OBSERVATION RESOLUTION PLAN RO-UKHPR1000-0006	Rev.: 1	Page: **12** / **12**
		GDA-REC-GNSL-005810	

APPENDIX A Gantt Chart