Hitachi-GE Nuclear Energy, Ltd.
UK ABWR GENERIC DESIGN ASSESSMENT
Resolution Plan for RO-ABWR-0001
Avoidance of Fracture – Margins Based on the Size of Crack-Like Defects

RO TITLE:	Avoidance of Fracture – Margins Based on the Size of Crack-Like Defects	
REVISION :	1	
Overall RO Closure Date (Planned):		31. Aug. 2016
REFERENCE DOCUMENTATION RELATED TO REGULATORY OBSERVATION		
Regulatory Queries	None	
Linked ROs	—	
Other Documentation	Hitachi-GE Document GA91-9901-0005-00001/XE-GD-0113, "UK ABWR GDA Preliminary Safety Report on Structural Integrity" Hitachi-GE Document GA91-9201-0003-00054/RD-GD-0001, "UK ABWR GDA Structural Integrity Classification Procedure" Hitachi-GE Document GA91-9201-0003-00056/RD-GD-0003, "UK ABWR GDA Defect Tolerance Assessment Plan" Hitachi-GE Document GA91-9201-0003-00055/RD-GD-0002, "UK ABWR GDA Weld Ranking Procedure" Hitachi-GE Document GA91-9201-0003-00057/G-TY-53082, "UK ABWR GDA Inspection Qualification Strategy" Hitachi-GE Document GA91-9201-0003-00058/G-TY-53081, "UK ABWR GDA Inspection Assessment Plan" Hitachi-GE Document GA91-9201-0003-00035/RE-GD-2010, "UK ABWR GDA Summary of the Design of the Reactor Pressure Vessel for UK ABWR"	

Scope of work :

RO-ABWR-0001 has been raised by the ONR to help to establish the Regulatory Expectations in relation of the topic of the avoidance of fracture and the demonstration of margins based on the size of crack like defects. This has been a major structural integrity topic in previous GDAs and the RO seeks to explain the expectations in the context of the UK ABWR. Hitachi-GE has already outlined the high level strategy for this topic, this approach was described in the Preliminary Safety Report for Structural Integrity issued during Step 1 of the GDA (GA91-9901-005-00001 Rev. A), with more detail provided during Step 2 of the GDA. The information contained within the RO is welcomed by Hitachi-GE as it will provide a useful reference from which the more detailed evidence documents described here will be developed. Hitachi-GE believes that the Actions identified by the ONR in RO-ABWR-0001 will be addressed by the programme of work outlined below. Whilst the plan is more detailed than that proposed by Hitachi-GE during Step 1 of the GDA, the overall intent is unchanged. In view of this, Hitachi-GE is confident in the understanding of the regulatory expectations and that the programme of work outlined below will be successful in resolving the RO to the ONR's satisfaction.

A summary and Hitachi-GE's interpretation of each of the RO Actions is provided below.

ACTION ROA-RO-ABWR-0001.A1.1 (Material Properties)
The ROA states that a materials property handbook should be produced suitable for supporting the fracture mechanics assessment. This should including minimum toughness values, with allowances for through life degradation, including

reference to supporting sources.

ACTION ROA-RO-ABWR-0001.A1.2 (Material Properties)
The ROA identifies the need for a strategy for undertaking fracture toughness testing on relevant material as part of the manufacturing process (forgings and welds) to underpin the minimum toughness values assumed in the material handbook. Such minimum values should be included in the Equipment Specifications for the components.

ACTION ROA-RO-ABWR-0001.A2.1 (Fracture Assessment)
The ROA covers the need to identify to the limiting locations for each component requiring a highest reliability claim i.e. in those components classified as either VHI or HI.

ACTION ROA-RO-ABWR-0001.A2.2 (Fracture Assessment)
The ROA states that the limiting defect size analysis for limiting locations should be established using elastic-plastic fracture mechanics methods with bounding transients and estimates of fatigue crack growth through life.

ACTION ROA-RO-ABWR-0001.A3.1 (Manufacturing Inspection)
The ROA states that the strategy for manufacturing inspections using techniques of established capability and providing sufficient redundancy, diversity and independence should be developed. In the case of critical locations (e.g. welds) the most rigorous inspections will be expected. The RO states that the ENIQ methodology, which incorporates the concept of technical justifications, provides a suitable framework for achieving inspection qualification for such critical locations.

ACTION ROA-RO-ABWR-0001.A3.2 (Manufacturing Inspection)
The ROA identifies the requirement for detailed inspection proposals to be provided, with technical reasoning, to demonstrate that the target defect sizes can be reliably detected taking into account their potential location, morphology and orientation.

ACTION ROA-RO-ABWR-0001.A4 (Overall Avoidance of Fracture Demonstration)
This ROA identifies the need to bring together the outputs from the material testing proposals, fracture assessment and manufacturing inspection to make the overall avoidance of facture demonstration by showing that structurally significant defects would be reliably detected using suitably redundant, diverse and where appropriate qualified inspection techniques, and that the minimum toughness properties assumed in the analysis work will be substantiated through fracture toughness testing of relevant material.

This RO Resolution Plan describes Hitachi-GE's current plan to address the Regulatory Observation however as the work develops we may choose alternative means to address this Regulatory Observation.

Description of work:

This section describes the work that Hitachi-GE plans to undertake to address the actions identified in the RO. The detailed programme is included in attached Table 1 below. The specific details of the components and regions for assessment in the context of RO-ABWR-0001 will depend upon the results of the UK Structural Integrity Classification methodology and the weld ranking methodology. The results of these assessments will not be available until later in Step 2. Once the locations for detailed assessment have been identified, the RO Resolution plan and the Gantt Chart will be updated to include the detailed schedule of further work.

ACTION ROA-RO-ABWR-0001.A1.1 (Material Properties)

There is a specific deliverable which shows a materials property handbook suitable for supporting the fracture mechanics assessment including minimum toughness values, with allowances for through life degradation, with reference to supporting sources.

To address this ROA, a report will be developed providing a compilation of material property data for use in the Defect Tolerance Assessments. It is proposed that that document will be maintained for the UK ABWR and will eventually become a repository for all related materials data, including the results of as-built properties. The report

will initially include data to underpin the fracture toughness properties used in the GDA Defect Tolerance Assessments, including the effects of through life degradation (thermal aging and irradiation embrittlement), mechanical properties and fatigue crack growth behavior. This report will include reference to key source information and will provide the evidence to support the material properties used in the Defect Tolerance Assessments and the basis for the selection of the various materials models, such as the JEAC4201 or EONY irradiation embrittlement models, or toughness correlations. The first issue of this report will be available during Step 3 of the GDA. The material properties used in the Defect Tolerance Assessment will be also used to inform the relevant equipment specifications.

ACTION ROA-RO-ABWR-0001.A1.2 (Material Properties)

There is a specific deliverable which is describing the strategy for undertaking fracture toughness testing on relevant material as part of the manufacturing process (forgings and welds) to underpin the minimum toughness values assumed in the material handbook, and to include such minimum values in the Equipment Specifications for the components.

To address this ROA, Hitachi-GE will produce a document which describes the strategy for material testing, based on a combination of testing required by the material specification (drop weight, charpy and tensile testing) and supplementary fracture toughness testing to support Defect Tolerance Assessment. This will be produced during Step 3 of the GDA and will include a strategy to ensure that appropriate minimum material properties are included within the equipment specifications and that provision is included in the design of forgings to include testing material, e.g. in prolongations. The report will also describe the approach for the inclusion of surveillance specimens inside the RPV, including the location of surveillance baskets and the type and number of surveillance materials.

ACTION ROA-RO-ABWR-0001.A2.1 (Fracture Assessment)

There is a specific deliverable which is describing an identification of limiting locations for each component requiring a highest reliability claim. Hitachi-GE should explain status of classification of VHI/HI components.

The Weld Ranking Report issued in March 2014 (GA91-9201-0003-00055) describes the procedure for identifying the limiting locations for Defect Tolerance Assessment and NDE evaluation. Whilst this procedure focuses on weld regions, selected regions of the parent material, such as nozzle crotch corner regions, will be included in this evaluation. The weld ranking report contains a methodology for the ranking of weld locations according to a combination of defect tolerance and NDE inspectability using a review process by an expert panel. The ranking methodology identifies the factors to be considered in the assessment, the scoring criteria (e.g. stress, fatigue usage, NDE access, geometry etc.) and their weighting factors. The methodology identifies a system, which combines the inspectability and defect tolerance scores, along with other factors such as the use of an in-house expert panel, and a check to ensure that the selection of locations is suitably diverse and representative. The results of the ranking will be included in the weld ranking report which will be issued during Step 2 of the GDA.

ACTION ROA-RO-ABWR-0001.A2.2 (Fracture Assessment)

There is a specific deliverable which is the limiting defect size analysis for limiting locations using elastic-plastic fracture mechanics methods with bounding transients and estimates of fatigue crack growth through life.

The Defect Tolerance Assessment Plan issued on 7th April 2014 (GA91-9201-0003-00056) provides a high level description of how the R6 Defect Tolerance Assessment methodology will be applied to VHI and HI components of the UK ABWR. This report summarises the key input data required to perform the Defect Tolerance Assessment and how the target margins are determined to demonstrate the structural integrity of welded components. The report covers the requirements for stress analysis, the material properties, the characterisation of defects, the treatment of residual stresses and how the R6 calculations will be performed. The methodology also takes cognisance of the ONR feedback from previous GDA assessments, which is consistent with the ONR expectations described in RO-ABWR-0001 including the specification of the margin on defect size at end of life and the restricted use of stable tearing arguments. It is intended to commence the initial assessment of selected RPV welds during Step 2 of the GDA. For the initial assessments, Hitachi-GE intends to adopt the Option 1 FAD and Level 1 residual stress profiles. The limiting defect sizes will be calculated based on the initiation toughness with the option of invoking ductile tearing for infrequent transients if needed. The target margin on defect size at end of life will be used to calculate the maximum allowable

start of life defect size. This will be used to inform the manufacturing inspection. A range of defect aspect ratios will be considered. To avoid excessive pessimism and the associated potential impact on the requirements for manufacturing inspection, more sophisticated assessment approaches may be used if required. Specific details will be presented as part of the initial assessment which are planned to commence during Step 2 of the GDA. The full scope of the assessment will not be finalized until the list of VHI and HI components has been developed in accordance with the Structural Integrity Classification Procedure and weld ranking procedure. Once these have been complete, the RO Resolution Plan will be updated to specifically identify the components where defect tolerance reports will be produced. It is anticipated that the programme will extend into Step 4 of the GDA. The results will be incorporated into Defect Tolerance Assessment reports for each identified limiting locations.

ACTION ROA-RO-ABWR-0001.A3.1 (Manufacturing Inspection)

There is a specific deliverable which is describing the strategy for manufacturing inspections using techniques of established capability and providing sufficient redundancy, diversity and independence. In the case of critical locations (e.g. welds) the most rigorous inspections will be expected. The ENIQ methodology, which incorporates the concept of technical justifications, provides a suitable framework for achieving inspection qualification for such critical locations.

The Inspection Qualification Strategy issued at the end of March 2014 (GA91-9201-0003-00057) describes the approach that will be applied to qualify the End of Manufacture (EoM) Non Destructive Examination (NDE) of the VHI and HI components. For each of the VHI and HI components, a manufacturing inspection strategy document will be produced containing details of the manufacturing inspections with evidence of diversity, redundancy and independence. High reliability NDE will be performed on VHI and HI welds at the End of Manufacture (EoM) to demonstrate that these components are free of defects that could threaten structural integrity through the lifetime of the plant. The reliability of this NDE will be assured by:

- Applying a principle of "Design for Inspectability" to UK ABWR plant that will provide ready access, wherever possible, for the deployment of NDE techniques. Most of the NDE applied at EoM will be performed at the fabricator's premises. This means that ready access will be made available for the application of NDE methods.
- Applying NDE methods (mainly ultrasonic inspection) that are suitable for the detection of planar manufacturing defects.
- Applying well established NDE techniques that are designed on sound physical principles.
- Qualifying the EoM NDE system (NDE procedure, equipment and personnel) using the ENIQ-based Methodology.
- Adopting measures during the implementation of the EoM inspection to assure the reliability of the NDE performed on the VHI and HI components.

Although this will concentrate on welds, this will also consider non-weld regions.

ACTION ROA-RO-ABWR-0001.A3.2 (Manufacturing Inspection)

There is a specific deliverable which is describing detailed inspection proposals, with technical reasoning, to demonstrate that the target defect sizes can be reliably detected taking into account their potential location, morphology and orientation.

The Inspection Assessment Plan document issued at the end of March 2014 (GA91-9201-0003-00058), describes how, during GDA, Hitachi-GE will demonstrate the reliability of the NDE performed at the end of manufacture on VHI and HI components. The GDA will perform a partial qualification on a sample of components that represent those cases that are most difficult for inspection. This partial qualification will include the production of a document, the inspection technical justification report, in the format of an ENIQ-based technical justification that will be assessed by an independent organisation that will act as a qualification body. The identification of these components will depend upon the outcome of the Structural Integrity Classification Procedure and weld ranking process. This is currently being finalized. Once complete, the RO resolution Plan will be updated to specifically identify the components where technical justification reports will be produced. This process will:

- Demonstrate that the proposed NDE techniques will be reliable in assuring that VHI and HI components will detect and reject planar defects at the QEDS and larger.
- Confirm that the proposed NDE can be qualified by applying the ENIQ-based Methodology.
- Demonstrate that Hitachi-GE understands the process of qualification according to the ENIQ-based Methodology.
- Provide a limited practical demonstration of the approach that will be used for qualifying the end of manufacture NDE.

ACTION ROA-RO-ABWR-0001.A4 (Overall Avoidance of Fracture Demonstration)

There is specific deliverables which bring together the outputs from the material testing proposals, fracture assessment and manufacturing inspection to make the overall avoidance of facture demonstration by showing that structurally significant defects would be reliably detected using suitably redundant, diverse and where appropriate qualified inspection techniques, and that the minimum toughness properties assumed in the analysis work will be substantiated through fracture toughness testing of relevant material.

For each VHI and HI component, Hitachi-GE plans to produce a topic report to describe the overall structural integrity safety case for the component. These topic reports will include evidence to substantiate the argument that the design is defect tolerant. These reports will be structured in a multi-legged format, similar to that proposed by the UK TAGSI, articulated in terms of claims, arguments and evidence. The third claim of the safety case will be that the VHI components are tolerant to through life degradation. This will be demonstrated by the results of the assessments of through-life crack growth, to show that such mechanisms will not threaten integrity over the life of the plant. This will combine the defect tolerance work with the inspection qualification work to provide a strong leg to the safety case. The intention to provide a first revision of the RPV topic report during Step 3 (May 2015), this will not include the results of the Defect Tolerance Assessment or the Inspection Technical Justifications, but it will include a discussion of the methodology being followed. The final version of the topic report will be issued during Step 4 to include a summary of the results from these assessments and reference to the detailed reports.

ACTION RO-ABWR-0001.5 – Hitachi-GE is required to demonstrate that the response(s) to this RO will be adequately captured within the safety and environmental cases for UK ABWR.

Hitachi-GE will identify all the impacted safety and environmental submission documents that will be affected by the RO e.g. PCSR, GEP, Master Document Submission List, Design Change Documentation, DRP, etc and implement the changes in accordance with its Commitments Capture Procedure when it updates its documentation.

Summary of impact on GDA submissions:

GDA Submission Documents	C/U	Related GDA RO Actions(s)	Submission Date to ONR
PSCR Structural Integrity Chapter (Step 4)	U	N/A	TBC
RPV Topic Report (Step 4)	U	N/A	TBC
Structural Integrity Classification Procedure	U	N/A	Mar-14
Structural Integrity Classification Report	C	N/A	Jun-14
Material Selection Report	C	ROA-RO-ABWR-0001.A1.1	Oct-14
Material Testing Strategy Report	C	ROA-RO-ABWR-0001.A1.2	Apr-15
Weld Ranking Procedure	U	ROA-RO-ABWR-0001.A2.1	Mar-14

Weld Ranking Report	C	ROA-RO-ABWR-0001.A2.1	Jun-14
Defect Tolerance Assessment Plan	U	ROA-RO-ABWR-0001.A2.2	Apr-14
Defect Tolerance Assessment Report	C	ROA-RO-ABWR-0001.A2.2	Aug-15
Programme and methodology for demonstrating the effectiveness of NDE	U	ROA-RO-ABWR-0001.A3.1	Mar-14
Inspection Qualification Strategy for VHI/HI Welds	U	ROA-RO-ABWR-0001.A3.1	Mar-14
Inspection Technical Justification Report	C	ROA-RO-ABWR-0001.A3.2	Aug-15
Equipment Specifications for VHI and HI Components (ASME Design Specification)	C	ROA-RO-ABWR-0001.A1.2 ROA-RO-ABWR-0001.A2.2 ROA-RO-ABWR-0001.A3.2	Mar-15
Topic Report Structure for VHI/HI Component	C	ROA-RO-ABWR-0001.A4	May-14
Topic Report Structure Main Body	C	ROA-RO-ABWR-0001.A2.2 ROA-RO-ABWR-0001.A3.2 ROA-RO-ABWR-0001.A4	May-15

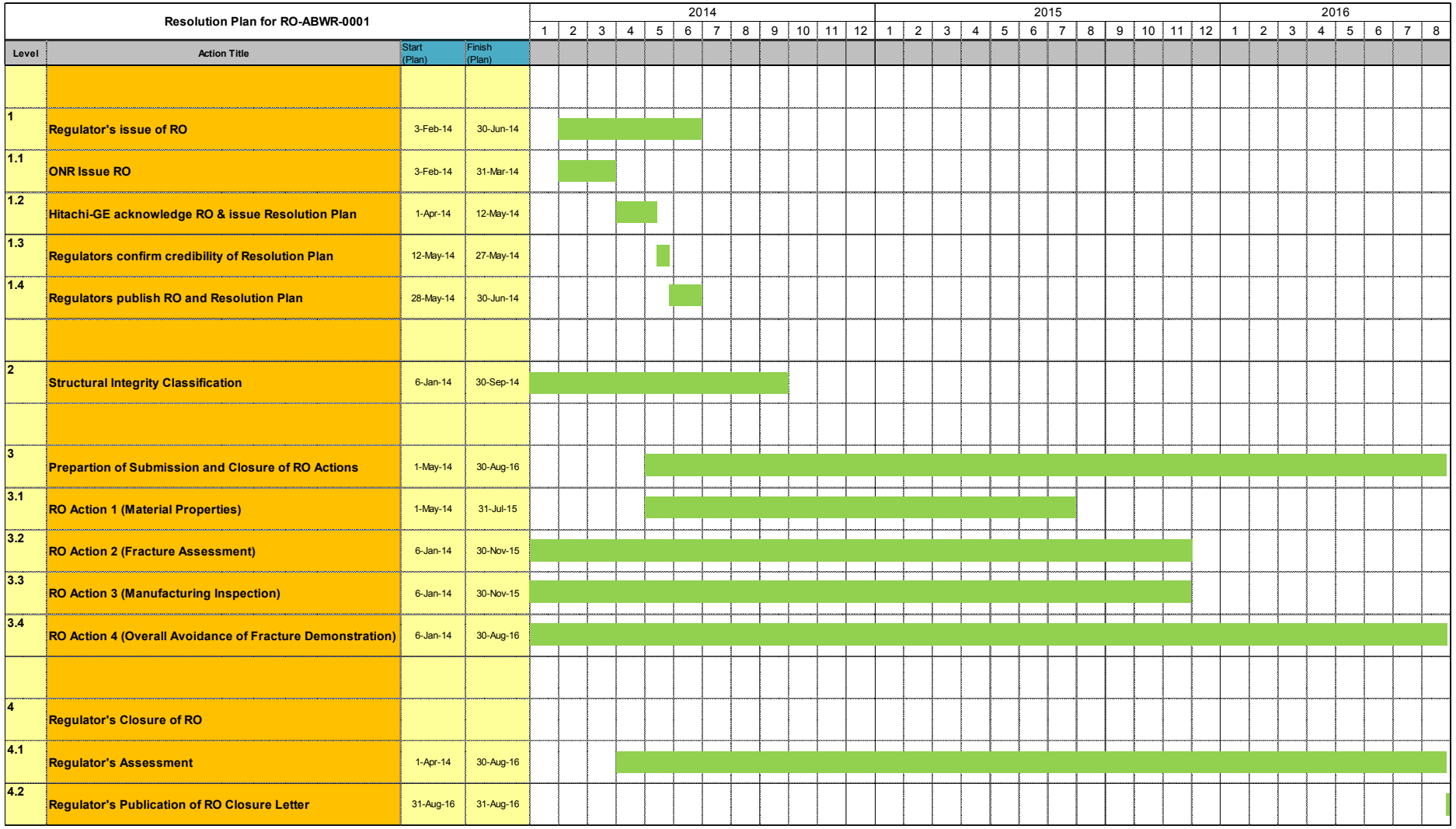
Programme Milestones/ Schedule:

See attached Gantt Chart (Table 1).

Reference:

None

Table 1 RO-ABWR-0001 Gantt Chart



Level	Action Title	Start (Plan)	Finish (Plan)
1	Regulator's issue of RO	3-Feb-14	30-Jun-14
1.1	ONR Issue RO	3-Feb-14	31-Mar-14
1.2	Hitachi-GE acknowledge RO & issue Resolution Plan	1-Apr-14	12-May-14
1.3	Regulators confirm credibility of Resolution Plan	12-May-14	27-May-14
1.4	Regulators publish RO and Resolution Plan	28-May-14	30-Jun-14
2	Structural Integrity Classification	6-Jan-14	30-Sep-14
3	Prepartion of Submission and Closure of RO Actions	1-May-14	30-Aug-16
3.1	RO Action 1 (Material Properties)	1-May-14	31-Jul-15
3.2	RO Action 2 (Fracture Assessment)	6-Jan-14	30-Nov-15
3.3	RO Action 3 (Manufacturing Inspection)	6-Jan-14	30-Nov-15
3.4	RO Action 4 (Overall Avoidance of Fracture Demonstration)	6-Jan-14	30-Aug-16
4	Regulator's Closure of RO		
4.1	Regulator's Assessment	1-Apr-14	30-Aug-16
4.2	Regulator's Publication of RO Closure Letter	31-Aug-16	31-Aug-16