

Hitachi-GE Nuclear Energy, Ltd.
UK ABWR GENERIC DESIGN ASSESSMENT
Resolution Plan for RO-ABWR-0023
Severe Accident Safety Case

RO TITLE:	Severe Accident Safety Case	
REVISION :	3	
Overall RO Closure Date (Planned):	30. Dec 2016	
REFERENCE DOCUMENTATION RELATED TO REGULATORY OBSERVATION		
Regulatory Queries	-	
Linked ROs	-	
Other Documentation	-	

Scope of work :
<p>Background ONR's guidance requires that severe accident analysis is undertaken to ensure that risks from a nuclear facility are reduced as low as reasonably practicable (ALARP). From ONR's assessment of Hitachi-GE's severe accident safety documentation provided to date it is considered that further information on the safety justification is required to demonstrate that regulatory expectations in the area of severe accident can be met. As the results, Regulatory Observation had been drafted. The aim of the Regulatory Observation is to ensure that Hitachi-GE's severe accident safety case strategy is appropriately defined, the scope of their severe accident safety case is complete; severe accident phenomena are appropriately considered, the severe accident analysis is suitable, engineered features, strategies & procedures are appropriate, and the release paths and behaviour of radionuclides are understood. As the response to the RO, Hitachi-GE has prepared for this resolution plan. <u>The resolution plan shows the project plan and delivery regarding to severe accident analysis during Step 3 and Step 4. After several actions were proceeded in Step 4, Hitachi-GE decided to add further actions on hydrogen management during shutdown mode to meet ONR's expectation. The objective of the hydrogen management is to minimise the potential radioactive releases to the environment. In Rev.3, Action 4.5.4, Action 4.5.5, and Action 4.5.6 were added to address the further consideration of hydrogen management during shutdown mode.</u></p> <p>Scope of Work The response to this RO is the delivery of the severe accident analysis for UK ABWR in GDA. This Resolution Plan shows some of the actions and milestones for preparation and delivery of Severe Accident (SA). The detailed programme of work is shown as below.</p>

Description of work:

ACTION # 1 – Severe accident safety case strategy

A1.1 : Plan for SA analysis

Hitachi-GE is required to clearly identify its severe accident safety case strategy for GDA, in terms of:

- Hitachi-GE needs to define its objectives for the severe accident analyses and to provide information on how it plans to demonstrate compliance with the UK regulatory principles. This should include how Hitachi-GE plans to show that the severe accident analysis has been used to:

- 1) identify any further reasonably practicable preventative or mitigating measures;
- 2) form a suitable basis for accident management strategies;
- 3) support the preparation of emergency plans for the protection of people;
- 4) determine the magnitude and characteristics of radiological consequences;
- 5) support the PSA of the facility's design and operation
- 6) demonstrate adequate understanding of the severe accident phenomena and accident progression.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- For 1), 2) and 5), we have already conducted severe accident analysis on unmitigated sequence and on mitigated sequence and these results have been described in the SAA topic report Rev. C ^[2]. New chapter "Severe Accident Safety Case Strategy" (Action 1.1.1) and SA analysis for mitigated sequence (Action 1.1.2) will be added in the SAA topic report. This chapter will include high level information on objectives and the relation to analyses.
- For 3) and 4), source term analysis will be conducted using MAAP code. The SAA topic report which describes the selection process and results of source term analysis will be submitted. (Action 1.1.3)
- For 6), severe accident phenomena and accident progression for the UK ABWR has already been described in the SAA topic report Rev.C ^[2]. Hitachi-GE will review this document and revise it if needed. (Action 1.1.4)

A1.2 : SA analysis, strategies, planned engineered features and procedures

Hitachi-GE is required to clearly identify its severe accident safety case strategy for GDA, in terms of:

- Hitachi-GE to provide information on its strategies for their severe accident safety case and to explain how the severe accident analysis, strategies, planned engineered features and procedures will form a coherent safety argument for the UK ABWR that meets UK regulatory guidance.

(RESOLUTION PLAN)

Severe accident analysis, strategies, planned engineered features and procedures have already been described in the SAA topic report Rev.C ^[2]. Hitachi-GE will review this document and revise it if needed. In addition, Hitachi-GE will take the following actions for the above requests.

- SA analysis for mitigated sequence (Action 1.1.2) will be added in the SAA topic report.
- The supporting document on emergency procedures will be submitted. (Action 1.2.1)
- The document, which summarises severe accident strategy and high level information on procedures, will be prepared and submitted. (Action 1.2.2)

A1.3 : Scope and objectives of the radiological consequence analysis

Hitachi-GE is required to clearly identify its severe accident safety case strategy for GDA, in terms of:

- Hitachi-GE needs to define the scope and objectives of the radiological consequence analysis i.e. how is Hitachi-GE identifying the scenarios to be considered, how will this support the preparation of emergency plans for the protection of the people.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Source term analysis will be conducted using MAAP code. The SAA topic report which describes the selection process and results of source term analysis will be submitted. (Action 1.1.3)
- It will be shown how this will support the preparation of emergency plans. (Action 1.3.1)

A1.4 : Selection process of postulated initiating events

Hitachi-GE is required to clearly identify its severe accident safety case strategy for GDA, in terms of:

- Hitachi-GE to explain the criteria for the selection of postulated initiating events and the different sets of multiple failures leading to a severe accident, for example, how have Hitachi-GE identified the severe accident scenarios that it has considered within its analysis to date.

(RESOLUTION PLAN)

Selection process of nine plant damaged states has already described in the document, “Event Sequence Analysis for Internal Event PSA at Power”^[3], “Event sequence analysis for internal event PSA at power”. Hitachi-GE will refer this document and explain outline of selection process and relationship between the document “Event Sequence Analysis for Internal Event PSA at Power”^[3] and severe accident analysis cases including mitigated sequence analyses and source term analyses in SAA topic report. (Action 1.4.1 and Action 1.4.2)

A1.5 : SA equipment specifications

Hitachi-GE is required to clearly identify its severe accident safety case strategy for GDA, in terms of:

- Hitachi-GE to identify the criteria used for severe accident analysis against which the performance of the engineered features, strategies and procedures can be judged, for example, how will Hitachi-GE show that their proposed severe accident engineered measures are suitable?

(RESOLUTION PLAN)

Severe accident analysis to show the effectiveness of strategies, planned engineered features and procedures have already been described in the SAA topic report Rev.C^[2]. In relation to response to A1.1, new chapter “Severe Accident Safety Case Strategy” will be added in the SAA topic report (Action 1.1.1). This chapter will include the section on criteria to judge whether the SA analysis has demonstrated that the SA measures are capable of performing their role. In addition, Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will issue the specifications required for SA engineered features. (Action 1.5)

A1.6 : Scope of emergency procedures

Hitachi-GE is required to clearly identify its severe accident safety case strategy for GDA, in terms of:

- Hitachi-GE to define the scope of the severe accident safety case for GDA, for example, what extent is it envisaged that the emergency procedures are going to be considered within GDA. If assumptions are going to be made on the future Licensee’s emergency capabilities or procedures these should be clearly stated.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- The management of offsite facilities like an emergency control centre is not in the scope of SAA. It will be shown what extent the emergency procedures are going to be considered within GDA. (Action 1.6)

Several intermediate deliverables will be defined step by step. All actions above will be completed by the end of August 2015.

ACTION # 2 – Completeness of the severe accident safety case

A2.1 : Completeness of the SA safety case

Hitachi-GE is required to demonstrate the completeness of their severe accident safety case, this should include:

- All operating modes (e.g. low power, shutdown, refueling, etc.) and all relevant facilities are considered.

(RESOLUTION PLAN)

All operating modes are considered in PSA. SA analysis at low power can be represented by that at power. In addition, Hitachi-GE will take the following actions for the above requests.

- The initiating event analysis of shutdown PSA and SFP PSA will be provided. (Action of PSA program)
- The source term evaluation of shutdown PSA and SFP PSA, including treatment on low power operation, will be evaluated. (Action of PSA program)
- Identification of potential facilities for severe accident and operation mode. (Action 2.1.1)

- Evaluation of consequences for other operation mode (not at power), from SFP and the facilities not containing at accident. (Action 2.1.2)

This action includes demonstration on which SA cannot occur in any facility other than the reactor and SFP.

- Examination of risk reduction countermeasures if need. (Action 2.1.3)
- Documentation on completeness of SA safety case considering above actions and PSA actions for the reactor and SFP (Action 2.1.4)

A2.2 : Internal and external hazard

Hitachi-GE is required to demonstrate the completeness of their severe accident safety case, this should include:

- A full analysis of the impact of potential internal and external hazards.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will justify that SA analysis for internal and external hazard can be represented by the analysis of nine plant damage states and containment failure modes in internal event (Action of PSA program, Action 2.2.1). If it will not be able to justify, the new PDS will be considered (Action of PSA program, Action 2.2.2).

A2.3 : Lessons learnt from Fukushima accident

Hitachi-GE is required to demonstrate the completeness of their severe accident safety case, this should include:

- An explicit description of the severe accident strategies and other outcomes resulting from the learning from the Fukushima accident.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Survey of the worldwide learning from the events at Fukushima, including stress test findings (Action 2.3.1)
- Investigation of items on the relevance to severe accident countermeasure's design (Action 2.3.2)
- Documentation on relationship between learning and UK ABWR design (Action 2.3.3)

A2.4 : Full analyses of events taking place over a long timescale

Hitachi-GE is required to demonstrate the completeness of their severe accident safety case, this should include:

- A full analyses of events taking place over a long timescale until a safe and sustainable position has been reached in line with the HM Chief Inspector's recommendations following the events at Fukushima.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will define the safe and sustainable position and provide the rational of these. A full analyses taking place over a long timescale will be conducted until a safe and sustainable position has been reached. (Action 2.4)

Several intermediate deliverables will be defined step by step. All actions above will be completed by the end of May 2015.

ACTION # 3 – Severe accident phenomena and analysis

A3.1 : Relevant severe accident phenomena

Hitachi-GE is required to identify and describe the relevant severe accident phenomena for the UK ABWR as well as providing the results severe accident analyses. This should include:

- A comprehensive list and description of all relevant severe accident phenomena for the UK ABWR; including a justification of any known severe accident phenomena that have been excluded from consideration in the UK ABWR analysis.

(RESOLUTION PLAN)

Severe accident phenomena for the UK ABWR has already described in the SAA topic report Rev.C^[2]. Hitachi-GE will review this document and revise it if needed. (Action 3.1)

A3.2 : Detail description of the input data files, the boundary conditions

Hitachi-GE is required to identify and describe the relevant severe accident phenomena for the UK ABWR as well as providing the results severe accident analyses. This should include:

- The severe accident documentation should include a description of the input data files, description of the boundary conditions of the analyses (including all assumptions) and a detailed explanation of the results. More specifically the results section should contain: information on the key phenomena seen in the analysis, a description of the performance and time to failure of the severe accident measures and the time to enact mitigation measures.

(RESOLUTION PLAN)

Detailed description of the input data files, the boundary conditions of the analyses and the explanation of the results have already been described in the SAA topic report Rev.C^[2]. Hitachi-GE will review this document and revise it if needed. In addition, Hitachi-GE will take the following actions for the above requests.

- The same information about source term analysis will be described in the SAA topic report. (Action 3.2)

A3.3: Impact of key uncertainties on the results

Hitachi-GE is required to identify and describe the relevant severe accident phenomena for the UK ABWR as well as providing the results severe accident analyses. This should include:

- An analysis of the potential impact of key uncertainties on the results. Sensitivity work should be undertaken to ensure that all uncertainties are dealt with appropriately.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will perform sensitivity analyses to confirm the impact of uncertainties on the results. (Action 3.3)

Several intermediate deliverables will be defined step by step. All actions above will be completed by the end of May 2015.

ACTION # 4 – Engineered features, strategies and procedures

A4.1 : Supporting document on emergency procedures

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- Substantiate the severe accident measures through the provision of detailed information on the actual design (for example, number, type, and location of connection points in the reactor building, mobile equipment; ways to provide coolant injection to the containment head, etc.) and their implementation into the severe accident management strategies.

(RESOLUTION PLAN)

We have already added the references about the information of severe accident measures in the SAA topic report Rev.C^[2]. Hitachi-GE will review this document and revise it if needed. In addition, Hitachi-GE will take the following actions for the above requests.

- The supporting document on emergency procedures will be submitted. (Action 1.2.1)

A4.2 : Document on severe accident strategy

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- Demonstrate the effectiveness of the severe accident management measures (see analysis above).

(RESOLUTION PLAN)

We have already conducted severe accident analysis on unmitigated sequence and on mitigated sequence and these results have been described in the SAA topic report Rev. C^[2]. Hitachi-GE will review this document and revise it if needed. In addition, Hitachi-GE will take the following actions for the above requests.

- The document, which summarises severe accident strategy and high level information, will be prepared and submitted. (Action 1.2.2)

A4.3 : SA equipment specifications

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- Describe the system safety classification and withstand capability on all of the proposed severe accident engineered features.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will issue the specifications required for SA engineered features. (Action 1.5)

A4.4 : Lessons Learnt from Fukushima accident

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- Describe the Fukushima related improvements (for example, backup building, mobile components, hydrogen management etc.).

(RESOLUTION PLAN)

The Fukushima related improvements have been already described in the SAA topic report Rev.C^[2]. Hitachi-GE will review this document and revise it if needed. In addition, Hitachi-GE will take the following actions for the above requests.

Hitachi-GE will take the following actions for the above requests.

- Survey of the worldwide learning from the events at Fukushima, including stress test findings (Action 2.3.1)
- Investigation of items on the relevance to severe accident countermeasure's design (Action 2.3.2)
- Documentation on relationship between learning and UK ABWR design (Action 2.3.3)

A4.5 : Supporting document on hydrogen management

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- Describe the measures for hydrogen management (and other combustible gases) during a severe accident inside and outside of the primary containment.

(RESOLUTION PLAN)

The measures for hydrogen management in the containment at operation mode have been already described in the SAA topic report Rev.C^[2]. In addition, Hitachi-GE will take the following actions for the above requests.

- Supporting document preparation on hydrogen management for reactor faults, including preliminary explanation (e.g. inside/outside containment, operation mode, relationship to containment flooding operation) (Action 4.5.1)
- The engineered features (e.g. flammable gas control function) and procedure will be described in the supporting document on emergency procedures, which will be submitted. (Action 4.5.2)
- Supporting analysis (Action 4.5.3)

The objective of the hydrogen management is to minimise the potential radioactive releases to the environment.

Considering the discussion with ONR, Hitachi-GE will update the above supporting documents (ALARP Discussion on Flammable gas control (AE-GD-0438) and Flammable Gas Control and Supporting Analysis in UK ABWR (AE-GD-0457)) and submit a new supporting document (Report on Physics Model and Benchmark of GOTHIC Code) considering the following items.

- Objectives of the Safety Case (Action 4.5.4)

- Analysis on Effects (Action 4.5.5)

- ALARP (Action 4.5.6)

A4.6 : Supporting document on emergency procedures

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- Provide information on the systems and strategies to depressurise the containment following a severe accident (for example, strategy, system design and filter design).

(RESOLUTION PLAN)

The systems and strategies for a severe accident have already been described in the SAA topic report Rev.C^[4]. In addition, Hitachi-GE will take the following actions for the above requests.

- The information will be described in the supporting document on emergency procedures, which will be submitted. (Action 1.2.1)
- The detail design information on filter venting is prepared. It will be described in “Basis of Safety Cases on Severe Accident Management System”. (Action 4.6.1)

A4.7 : ALARP evaluation

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- Provide documentation of the optioneering process which has been, or will be, done to consider what severe accident design measures are reasonably practicable for the UK ABWR. Hitachi-GE should explain why the design of the UK ABWR represents Relevant Good Practice and follows the ALARP principle in relation to severe accidents; this should include a review of international good practice in the severe accident area. The response to this action should include: consideration of methods / technologies for confining a molten core, passive methods of core or containment cooling, methods for further increasing grace / response times, methods of further capturing / reducing fission products inside containment, the design of the containment head flange and other systems to protect from containment leakage, passive methods for flammable gas control, and any other relevant severe accident measures considered elsewhere.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will show the discussion on why our SA countermeasures are reasonably practicable.
 - 1) Consideration of methods / technologies for confining a molten core (Action 4.7.1)
 - 2) Passive methods of core or containment cooling (Action 4.7.2)
 - 3) Methods for further increasing grace / response times (Action 4.7.3)
 - 4) Methods of further capturing / reducing fission products inside containment (Action 4.7.4)
 - 5) Design of the containment head flange and other systems to protect from containment leakage (Action 4.7.5)
 - 6) Passive methods for flammable gas control (Action 4.7.6)
 - 7) Any other relevant severe accident measures considered elsewhere (Action 4.7.7)

A4.8 : Supporting document on emergency procedures

Hitachi-GE is required to provide a clear description and justification of all the engineered features, strategies and procedures to deal with severe accidents for the UK ABWR. This should:

- A description of the overall strategy/ies to deal with severe accidents at a UK ABWR, that will serve as the basis for the development of severe accident management guidelines and which should be underpinned by severe accident analysis.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- The document, which summarises severe accident strategy and high level information on procedures, will be prepared and submitted. (Action 1.2.2)

ACTION # 5 – Release paths and behaviour of radionuclide

A5.1 :

Hitachi-GE is required to identify and describe the possible release paths and the behaviour of radionuclide for the UK ABWR. This should include:

- An analysis of releases of radionuclide following a severe accident from the UK ABWR (i.e. severe accident source terms).

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Source term analysis will be conducted using MAAP code. The SAA topic report which describes the selection process and results of source term analysis will be submitted. (Action 1.1.3)

A5.2 : Release paths and the behavior of radionuclide

Hitachi-GE is required to identify and describe the possible release paths and the behaviour of radionuclide for the UK ABWR. This should include:

- A justification of the amount of fission products to be retained within the containment (e.g. retention of fission products in the suppression pool) and a description of the behaviour of radionuclide (in-vessel and ex-vessel) following a severe accident.

(RESOLUTION PLAN)

The analysis model and the benchmark results for fission products behaviour have already been described in the MAAP topic report. Hitachi-GE will review this document and revise it if needed. (Action 5.2)

A5.3 : Containment failure mode for source term analysis

Hitachi-GE is required to identify and describe the possible release paths and the behaviour of radionuclide for the UK ABWR. This should include:

- A description of the primary containment failure mode/s assumed in the analyses, this should include information on conditions inside the reactor building (outside of the primary containment).

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will add the description of the PCV failure mode assumed in the source term analyses in the SAA topic report. Impact of PCV failure mode on FP release will be confirmed. (Action 5.3)

A5.4 : Description of all other possible release paths

Hitachi-GE is required to identify and describe the possible release paths and the behaviour of radionuclide for the UK ABWR. This should include:

- A description of all other possible release paths following a severe accident considered for the UK ABWR. This information should be provided in the appropriate topic report. Links and interfaces with other aspects of the UK ABWR safety case need to be identified.

(RESOLUTION PLAN)

Hitachi-GE will take the following actions for the above requests.

- Hitachi-GE will add the description of the PCV failure mode assumed in the source-term analyses in the SAA topic report. Impact of PCV failure mode on FP release will be confirmed. (Action 5.4)

Several intermediate deliverables will be defined step by step. All actions above will be completed by the end of May 2015.

Summary of impact on GDA submissions:

<u>GDA Submission Document</u>	<u>Submission Date to ONR</u>
Topic Report on Severe Accident Analysis Rev. D	31 December, 2014
Supporting Document on Emergency Procedures	31 March, 2015
Supporting Document on SA Equipment Specifications	31 March, 2015
Supporting Documents on Sensitivity Analysis	31 May, 2015
Supporting Documents on Lessons learnt from Fukushima accident	31 May, 2015
Topic Report on Severe Accident Analysis Rev. E	31 August, 2015
Supporting Documents on ALARP Evaluation	31 October, 2015
<u>ALARP Discussion on Flammable gas control, AE-GD-0438 Rev.1</u>	<u>30 December 2016</u>
<u>Flammable Gas Control and Supporting Analysis in UK ABWR, AE-GD-0457 Rev.3</u>	<u>30 December 2016</u>
<u>Report on Physics Model and Benchmark of GOTHIC Code</u>	<u>30 December 2016</u>
Generic PCSR Chapter 26: Beyond Design Basis and Severe Accident Analysis Rev. B	24 August 2015

Programme Milestones/ Schedule:

See attached Gantt Chart (Table 1).

Reference:

- Ref[1] Generic PCSR Chapter 26: Beyond Design Basis and Severe Accident Analysis Rev. A, GA10-9101-0101-26000
- Ref[2] Topic Report on Severe Accident Phenomena and Severe Accident Analysis Rev. C , GA91-9201-0001-0002
- Ref[3] Event Sequence Analysis for Internal Event PSA at Power Rev. 2 , GA91-9201-0003-00151
- Ref[4] Basis of Safety Cases on Severe Accident Management System, Rev. A, GA91-9201-0002-00021

Table 1 RO-ABWR-0023 Gantt Chart

