REGULATORY OBSERVATION

REGULATOR TO COMPLETE

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Agreement of Resolution Plan Required by:	1st June 2015
Resolution of Regulatory Observation required by:	
TRIM Ref.:	2015/136397
Related RQ / RO No. and TRIM Ref. (if any)**:**	RQ-ABWR-0515 – 2015/136677
Observation title:	UK ABWR Probabilistic Safety Analysis: Level 2 PSA methodology
Technical area(s) 4. PSA	**Related technical area(s)** 18. Severe Accident Analysis 9. Reactor Chemistry 10. Radiation Protection & (Level 3 PSA)

Regulatory Observation

Summary

ONR's assessment during Step 3 of GDA of the Hitachi-GE methodological aspects of the UK ABWR Level 2 PSA for internal events at power (Ref.1) has identified shortfalls in the completeness of the Level 2 PSA Plant Damage States (PDS), Containment Event Trees (CET), Release Categories and documentation. The objective of this Regulatory Observation (RO) is to state ONR's expectations related to the UK ABWR Level 2 PSA and request Hitachi-GE to respond to the shortfalls identified by ONR's review.

Background and Regulatory Expectations

The formulation of the Level 1 and Level 2 PSA for internal events provides the basic framework and set of consistent assumptions that lays the groundwork for the assessment of external events and other operating modes. As such, special care is deemed appropriate to ensure that the framework is sufficiently robust to avoid unnecessary biases that may distort the risk profile when these external events and other operating nodes are incorporated in the evaluation.

ONR's assessment during Step 3 of GDA of the Hitachi-GE methodological aspects of the UK ABWR Level 2 PSA for internal events at power (Ref.1) has identified shortfalls in the completeness of the Level 2 PSA Plant Damage States (PDS), Containment Event Trees (CET), Release Categories, and documentation. In particular, the review has highlighted the following general concerns that are summarised below. Specific examples are provided in Ref.3.

<u>Documentation of the Level 1/ Level 2 PSA interface</u>

While examination of the detailed model supports the Requesting Party (RP) assertion that dependencies are adequately treated, it is judged important that the manner in which dependencies are handled be documented within the report.

The Level 2 PSA documentation does not adequately explain the interface between Level 1 and Level 2 PSA models in the transfer of the following information across the Level 1 to Level 2 PSA interface and how this interface will adequately ensure the dependencies identified in ONR's PSA TAG are addressed:

- Support system dependencies
- Human dependencies
- Individual cutsets

- Success logic terms
- "NOT" logic effects

Plant Damage States

The PSA does not represent all accidents that end in core damage by a specific PDS. It is ONR's expectation that the sum of CDF from PDSs should represent the total CDF. This total CDF should then be used to enter the Level 2 PSA and its CETs to determine the course of the severe accidents with respect to phenomenological effects, containment failure modes, additional mitigative actions, and resulting source term. In addition to having specific PDSs identified, each PDS should then also have an associated CET that is used to model the severe accident progression paths subsequent to core damage.

Expanded List of PDSs to Address Critical Level 2 Effects

The proposed quantification process appears to neglect radionuclide release characterization dependencies from the Level 1 PSA model such as timing effects or certain functional dependencies. Specific examples of shortfalls in the approach adopted to consider accident sequences in the CETs are provided in Ref.3.

Containment Event Trees

Because of the low calculated risk profile for the UK ABWR for internal events, the dismissal of phenomena or accident sequences previously judged to be low contributors may not be appropriate for the UK ABWR.

The proposed accident progression event trees appear simplistic at this stage, do not address all aspects of the severe accident progression, and dismiss without robust justification, certain severe accident phenomena from further consideration in the CETs. This approach does not meet regulatory expectations as these aspects may be the dominant failure modes of containment. Specific examples are provided in Ref. 3.

Future plant modifications, procedure changes, or consequence assessments can be influenced by these phenomena or aspects of the severe accident progression. It is therefore ONR's expectation that these are included in the probabilistic model and characterized probabilistically with the available scientific evidence.

CET Required for TW, TC, BOC, ISLOCA

The Level 2 PSA for containment failure sequences (TW, TC) and bypass sequences (ISLOCA, BOC) does not appear to evaluate the realistic plant capability to cope with severe accident sequences. By assuming the complete loss of mitigating systems at containment failure, the core damage frequency and the radionuclide release frequencies can be significantly overestimated biasing the risk profile and thereby biasing the search for effective safety enhancements. It is ONR's expectation that the Level 2 PSA is a realistic evaluation of plant capabilities that allows the identification of the most risk significant sequences and thereby allows the identification of possible procedures or equipment modifications that would be advantageous in reducing these risk significant challenges, in particular:

- A realistic assessment of the risks associated with accident sequences (e.g., TW, ISLOCA, BOC, and TC) should be provided instead of making assumptions regarding their mitigation potential.
- Accident mitigation measures (see example in Ref. 3)
- A CET development is judged important to display the release pathway and any active or passive mitigation measures available to reduce the radionuclide release for each of the above identified accident sequences.

Accident Progression Analyses

Deterministic calculations that adequately portray the radionuclide release potential for diverse release paths and mitigating systems are an important element of the PSA.

The SAA report (Ref.2) provides selected mitigating system calculations for TQUV and LOCA sequence

challenges. However, very limited or no mitigating system analysis is performed for:

- TQUX
- ISLOCA
- BOC
- Delayed SBO – TB.
- Small LOCA

The basis for limiting the scope of the accident progression analysis to only two postulated accident types are not clear. ONR expectation is that severe accident analyses, including mitigating systems analyses should be provided for the additional key accident sequences noted above to support the Level 2 PSA.

Containment Failure Modes and Other Radionuclide Release Paths

The containment failure envelop is presented in Figure 5.2-1 of UK ABWR Level 2 PSA (Ref.1). It appears to be relatively restrictive in both pressure and temperature compared with typical US BWR containment failure curves. In addition, no criteria for failure are provided and no size or location of possible failures are discussed.

Specifically, containment failure modes or release paths do not include the following:

- Debris direct interaction induced failure modes (e.g., for LDW tunnels and associated outer hatch).
- Vapor suppression failure.
- Hydrodynamic loads.
- Negative pressure loading.
- High temperature and pressure challenges to the containment Liner, Tunnel and Hatches.
- Containment vent (e.g., with filter, without filter, DW without filter, WW without filter).
- RPV Vent (if applicable).
- Containment flooding (from external water sources) effects.

Release Categories

The radionuclide release categories fail to recognize the following:

- Status of containment sprays (e.g., no cases with sprays on after containment failure).
- Status of inerting.
- RPV pressure at RPV breach for TW and TC.
- DCH for TQUV (eg. In case of RPV repressurization due to potential failures or blockage of the SRVs due to high temperatures and substantial debris particulates), TW, TC sequences (Ref.3 provides further clarification).
- Location of containment failure (drywell, wetwell airspace, wetwell water space).
- Size of containment failure.
- No distinction among the following PDS regarding Release Categories (TQUX, TQUV, LOCA, TB-Late SBO).
- No containment bypass calculation.
- No RPV rupture initiator Release Category.
- No vapor suppression failure Release Category.
- No WW water space failure Release Category.

- No difference in failure size or locations between TC and TW.
- Status of venting (e.g., whether the vent is opened and left open).
- LOCA events with either containment failure or leakage.

The release categories developed in the Level 2 PSA do not appear to represent a comprehensive group that covers the spectrum of releases from leakage through containment failure or bypass as expected by ONR. The limited number of source term calculations and the lack of characterization of certain accident progression sequences do not meet regulatory expectations in ONR's PSA TAG.

References:

1. Internal Event Level 2 PSA at-power, GA91-9201-0001-00103 Rev. 1.
2. Severe Accident Phenomena and Severe Accident Analysis, GA91-9201-0001-00024 Rev. D.
3. RQ-ABWR-0515 Level 2 PSA for internal events at power – example of findings. TRIM 2015/136677.

Regulatory Observation Actions

RO-ABWR-000048.A1: Level 1/Level 2 interface PSA documentation

Hitachi-GE is requested to update the Level 2 PSA documentation so that it includes a clear explanation of how the model logic and dependencies from the Level 1 (functional, common cause, human, spatial) are transferred into the Level 2 model and are properly treated.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0048.A2: Plant Damage States

1. Hitachi-GE is requested to expand the number of PDSs that are used to characterize the Level 1 end states. Specifically, all Level 1 accident sequences that involve core damage should be assigned to a PDS that adequately represents the key characteristics of the accident sequence.

2. Hitachi-GE is requested to develop a CET for each PDS.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0048.A3: Severe accident phenomena and other aspects of the severe accident progression

Hitachi-GE is requested to review and appropriately expand the severe accident phenomena and other aspects of severe accident progression treated in the CETs. Some aspects that ONR currently considers are not adequately addressed are:

- Steam explosions (in-vessel)
- Deinerted operation including hydrogen deflagration.
- Potential introduction of oxygen in the containment during severe accident progression (eg. after containment venting and containment spray operation, break of instrument lines inside containment etc.).
- Consideration of variations in the analysed sequence that would influence the conclusion related to containment remaining steam inerted after venting.
- Hydrogen effects on containment vent pathway.

- Pathway for release of hydrogen (and fission products) to the Reactor Building.
- SRV reclosure at elevated containment pressures that affect subsequent DCH assessments.
- Suppression pool pH characterization during modeled severe accidents.
- Filtered vent versus non-filtered vent pathway.
- DW and RPV vents regarding their effect on radionuclide releases.
- Containment flooding effects regarding their effect on radionuclide releases.
- Suppression pool bypass due to the following:
    - Low suppression pool water level.
    - Vacuum breakers stuck open.
    - SRV tail pipe rupture.
    - In addition, the effects of vapor suppression failure are not addressed that could lead to containment failure and suppression pool bypass with reduced radionuclide release DF.
- RPV rupture, including:
    - The possibility that sludge, drywell fibrous debris, or insulation debris can be swept into the suppression pool and block the ECCS suction strainers.

      or
    - Alternatively adversely affect the continued operation of ECCS pumps or impact cooling of the fuel in the core.
- Operation of sprays as radionuclide release mitigation measure before and after containment.
- Revision and documentation of the claims on the recovery of injection any time before RPV breach to recognize the probability that the RPV penetrations and lower head may be insulated from cooling water and that attack of these may not be prevented by water addition.
- Accident mitigation measures.
- Expansion of the PDSs and CETs to explicitly model TW, TC, BOC, and ISLOCA accident sequences.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0048.A4: Accident Progression Analyses

1. Hitachi-GE is requested to extend the severe accident analyses, including mitigating systems analyses to cover key accident sequences in the Level 2 PSA in line with regulatory expectations (see action RO-ABWR-023.A1 and background section).

2. Hitachi-GE is requested to demonstrate that the radionuclide release calculations used to support the Level 2 PSA are performed for sufficient time to reach a stable release.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan

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RO-ABWR-0048.A5: Radionuclide release path characterisation

As an extension of RO-ABWR-0023.A5, Hitachi-GE is requested to explicitly characterise the radionuclide release paths in the Level 2 PSA based on a detailed containment failure analysis (RO-ABWR-00046.A6) from locations and timing affected by the debris location that include but are not limited to containment DW head, lower DW tunnel, WW airspace and WW water space.

This should include representation of the impact of the Reactor Building systems, instrumentation, access, integrity during the postulated failure mode, including leakage to the Reactor Building.

The identification of the failure locations and associated criteria that are violated should be documented.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0048.A6: Containment performance analyses

As an extension of RO-ABWR-0023.A5, Hitachi-GE is requested to perform a comprehensive containment performance analyses to identify the potential radionuclide release paths following a severe accident.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0048A7: Release category groups

Hitachi-GE is requested to revise the release category groups in line with the outcome of A5 and A6 so that they accurately reflect the timing and magnitude of the release.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0048.A8: Mitigation measures

1. Hitachi-GE is requested to verify whether there are additional mitigation measures that need to be incorporated into the PSA so the Level 2 PSA provides a realistic evaluation of plant capabilities that allows the identification of the most risk significant sequences; and therefore it allows the identification of possible procedures or equipment modifications that would be advantageous in reducing these risk significant challenges.

2. Hitachi-GE is requested to characterize the systems response under severely degraded conditions of core melt progression. These should include but not be limited to:
   - ECCS/DW spray operation with core debris and other debris discharged to the suppression pool where suction strainers are present.
   - Credit for mitigation systems after ISLOCA or BOC core damage.
   - SRV operability under core melt progression.
   - Check valve operability for RPV injection systems during core melt progression.
   - ECCS operability with containment venting of a saturated suppression pool.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0048.A9: key assumptions and sensitivity analyses

As an extension of RO-ABWR-023. A3, Hitachi-GE is requested to identify the key assumptions and uncertainties related to the Level 2 PSA and supporting analyses, provide justification, and undertake sensitivity analyses to understand the impact on the Level 2 PSA results.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan

REQUESTING PARTY TO COMPLETE

Actual Acknowledgement date:	
RP stated Resolution Plan agreement date:	