Enclosure 2

MFN 14-052, Revision 1

GEH Revised Response to RAI 06.02.01.01.C-1

Public Version

This is a non-proprietary version of Enclosure 1, from which the proprietary information has been removed. Portions of the document that have been removed are identified by white space within double brackets, as shown here [[   ]].

NRC Request for Additional Information 06.02.01.01.C-1, Entire Text (for reference):

The purpose of this RAI is to request additional information for the staff to conduct the safety evaluation of GE-Hitachi's design certification renewal application Sections 6.2.1, 6.2.2 and associated Technical Specifications.

1. *In the Enclosure 1 of DC renewal application package (ML 110040176), it stated that the design control document (DCD) changes are limited to correcting the containment peak pressure analysis to reflect a more limiting line break that GEH identified and discussed in MFN 09-306 (June 8, 2009, ML 100640164). In MFN 09-306, it referred to the report NEDO-33372, "Advanced Boiling Water Reactor (ABWR) Containment Analysis." However, the NEDO-33372 report was withdrawn from NRC's review (ML 100890313). What are the documents used to support the changes made for DCD Revision 5, Sections 6.2.1 and 6.2.2? Note that the References section (Section 6.2.8) in the DCD Revision 5 does not list any new or revised documents to reflect the changes. Provide such a document(s) and related supporting documents or calculations for audit.*

2. *Chapter 6 Change List (25A5675AH), Item 18 (Sec. 6.2.1.1.3.3.1.2) states that the lower drywell flooding is not modeled. Explain why and provide justification for the lower drywell flooding not being modeled.*

3. *Chapter 6 Change List (25A5675AH), Item 19 (Sec. 6.2.1.1.3.3.1.2) states that the previous assumption is removed and the structure heat sinks are modeled. Provide tables for the structural heat sinks (guidance is provided in Regulatory Guide 1.206, Tables 6-4A through 6-4D). With respect to modeling heat sinks for heat transfer calculations, provide and justify the use of heat transfer coefficient, especially, the condensing heat transfer coefficient or model, and computer mesh spacing used for heat sinks. Justify the steel-concrete interface thermal resistance used for steel-lined concrete heat sinks, as well as the heat transfer correlations used in heat transfer calculations. Provide a configuration control mechanism by which the heat sinks used in analyses will be verified for the as-built plant so that the results from the FSAR analyses can be concluded to be valid for the as-built plant.*

4. *Chapter 6 Change List (25A5675AH), Item 23 (Sec. 6.2.1.1.3.3.2) eliminates the wording on instrument delay 0.5 sec. Is the instrument delay included in the 5-sec closing time? Otherwise, justify the removal of the delay.*

5. *Chapter 6 Change List (25A5675AH), Item 24 (Sec. 6.2.1.1.3.3.2.1) removes the first two assumptions of Sec. 6.2.1.1.3.3.2.1. The original assumption (4) is also removed but not shown in the list. Provide justification for all removals.*

6. *Chapter 6 Change List (25A5675AH), Item 26 (Sec. 6.2.1 .1.3.3.2.3) indicates that the short-term MSLB (Sec. 6.2.1.1.3.3.2.3) has more severe drywell temperature response than before (i.e. 177.2°C vs. 169.7°C). Explain why and provide justification for such a significant difference.*

7. *The negative pressure design evaluation as shown in Sections 6.2.1.1.4.1 and 6.2.1.1.4.2 has significantly changed. Explain why and provide justification for these changes. Provide details regarding how the events are analyzed, including model development, verification and validation, and calculations for audit.*

Note: Text in **RED FONT** applied to the NRC RAI 06.02.01.01.C-1 Part 3 presents the changes from Revision 0 to Revision 1. All other text in the entire document remains equivalent to the Revision 0 responses and does not change in this Revision 1.

For this revision, GEH proprietary information within text and tables is identified by a dark red font with a dotted underline placed within double square brackets [[This sentence is an example.{3}]]. GEH proprietary information in figures or equation objects is identified with double square brackets before and after the object. In all cases, the superscript notation {3} refers to Paragraph (3) of the affidavit included in the transmittal providing the basis for the proprietary determination.

GEH References Applicable to RAI Responses:

1. Letter, USNRC to Jerald G. Head (GEH), Subject: "Request for Additional Information Letter Number 1 Related to Chapters 6, 8, and 19 for GE-Hitachi Nuclear Energy Advanced Boiling-Water Reactor Design Certification Rule Renewal Application," MFN-14-021, ML14114A566, April 24, 2014.
2. NEDO-33372, Revision 0 "Licensing Topical Report, Advanced Boiling Water Reactor (ABWR) Containment Analysis," September 2007
3. Letter, R. E. Kingston (GEH), Subject: "ABWR Standard Plant Design Certification Renewal Application Design Control Document, Revision 5, Tier 1 and Tier 2," MFN 10-342, Docket No. 52-001, December 7, 2010.
4. Letter, J. Head, (GEH), Subject: "Response to NRC Request for Information and Supplemental Information Regarding Two 2002 GEH 10 CFR Part 21 Notifications," MFN 09-306, Docket 52-001, June 8, 2009.

NRC Request for Additional Information 06.02.01.01.C-1, Part 1

In the Enclosure 1 of DC renewal application package (ML110040176), it stated that the design control document (DCD) changes are limited to correcting the containment peak pressure analysis to reflect a more limiting line break that GEH identified and discussed in MFN 09-306 (June 8, 2009, ML100640164). In MFN 09-306, it referred to the report NEDO-33372, "Advanced Boiling Water Reactor (ABWR) Containment Analysis." However, the NEDO-33372 report was withdrawn from NRC's review (ML 100890313). What are the documents used to support the changes made for DCD Revision 5 Sections 6.2.1 and 6.2.2? Note that the References section (Section 6.2.8) in the DCD Revision 5 does not list any new or revised documents to reflect the changes. Provide such a document(s) and related supporting documents or calculations for audit.

GEH Response to RAI 06.02.01.01.C-1, Part 1:

A primary purpose of NEDO-33372 (Reference 2) was to identify and discuss changes to the ABWR Feedwater Line Break (FWLB) containment analysis for peak containment pressure

reported in the existing certified ABWR Design Control Document (DCD). The correction to the peak containment analysis for a more limiting break, which GEH had referred to in Enclosure 1 to MFN 10-342 (Reference 3, ML 1110040176), corresponds to a change in the FWLB blowdown modeling that had been applied for the FWLB analysis documented in NEDO-33372, but is not implemented in the revised ABWR DCD. . This change had been originally implemented in NEDO-33373 in response to Potential Safety Concern ("PSC") 240, "Possible Non-Conservative Containment Analysis Assumptions (ABWR/Lungmen)" that was identified in MFN 09-306 (Reference 4). The FWLB blowdown characteristics used in the Reference 2 analysis was obtained from a detailed FWLB blowdown analysis developed by and for a foreign ABWR licensee plant. This revised analysis had initially been considered representative and appropriate for application to the US ABWR. However, after further review it was determined that the existing ABWR DCD modeling of the FWLB was appropriate for the US ABWR FWLB analysis application. Therefore, it was also determined that PSC 0240 and the revised FWLB containment analysis that was implemented in NEDO-33372 to address PSC 0240, do not apply to the US ABWR. For the revised DCD analysis the existing DCD FWLB modeling is retained with only a minor revision that is discussed below.

Analysis changes that were originally implemented in NEDO-33372 to address other PRC concerns that were identified in MFN-09-306, including; PRC 00-26, "Non-Conservative Estimation of Decay Heat from Actinides", PRC 05-42 "Worst Single Failure for Suppression Pool Temperature Analysis" and PRC 03-69, "ABWR Main Steam Line Break Containment Response Analysis", have been implemented for the revised containment analyses of ABWR DCD Revision 5. Changes associated with the revised containment analysis for DCD Revision 5 are described in the revised DCD discussion. There are no new documents that have been issued or new references cited that were required to support the changes for the DCD revision. Although NEDO-33372 is no longer directly applicable to the ABWR for the reasons discussed above, there is certain information that remains applicable to the ABWR renewal application. Therefore, rather than revise NEDO-33372, the information is proposed to be included in the ABWR DCD, as described below. In this manner, the ABWR DCD will not include NEDO-33372 as a reference and the NRC will not need to re-initiate its review of NEDO-33372.

The following identifies major and minor changes associated with the DCD revision for Chapter 6.2.

Major Changes:

These are two other major analysis changes that were originally identified in Reference 2 and that have been implemented in the revised ABWR containment analysis for DCD Revision 5:

- Decay heat using 2 sigma uncertainty for the long-term containment analyses
- Containment vent system modeling changes

Each is discussed below:

Decay heat using 2-sigma uncertainty for Long-Term Analyses.

The original certified ABWR DCD long-term containment analysis was performed with decay heat curves based on nominal ANSI/ANS–5.1 (1979). For certain safety analyses (e.g., Emergency Core Cooling Systems LOCA), there was a 2 sigma uncertainty adder that was applied to the decay heat curves to ensure conservatism, but this was not done or required for the long-term containment analysis.

Subsequent to the original certified analyses, GEH determined that additional actinides and activation products that were not in the ANSI/ANS-5.1 (1979) standard affect the decay heat curves. The activation products, while individually negligible, when summed together are non-negligible. These summation calculations determined that the inclusion of the actinides, other than U239 and Pu239, and activation products does not significantly affect decay heat calculations used for the earlier periods of the long-term containment response. However, for time after shutdown greater than 10^4 seconds (~ 3 hours), the effect on total decay heat can be significant and can therefore affect the results predicted at later periods in the long-term containment response analysis. To ensure conservatism in the revised long-term containment analyses of Chapter 6.2 a bounding decay heat was generated using ANSI/ANS-5.1 (1994), which includes contributions from additional actinides and activation products. Additionally, the revised long-term containment analyses that are described in Chapter 6.2 are performed with a 2-sigma uncertainty on decay heat.

<u>Decay Heat for Short-Term Containment Analysis</u>

The decay heat inputs for the ABWR DCD short-term analysis are based on ANSI/ANS 5 (1971) with a 20% margin adder which is consistent with the requirements of 10CFR50 Appendix K. This input is the same for both the certified and revised ABWR analysis and is not impacted by the required changes for the long-term decay heat inputs.

Containment Vents Model

The ABWR drywell is divided into upper and lower drywells, connected by rectangular drywell connecting vents. Large break LOCAs (e.g., Main Steam Line Break (MSLB) and Feedwater Line Break (FWLB) occur in the upper drywell. The GEH containment analyses model the upper and lower drywell as a single node volume. In order to model the drywell as a single volume, it is necessary to include the drywell connecting vent (DCV) loss coefficients to determine the total overall vent flow loss coefficient from drywell vertical vent system entrance to the horizontal vent exit in the suppression pool. See NUREG-1503, Section 6.2.1.2, for additional details. In the containment analysis for the certified ABWR DCD, the main vent system model did not capture some of the key features that impact the short-term containment response and thus the pool swell loads.

The ABWR vent system is similar to the Mark III design. The Mark III has a weir annulus in the drywell and 3 rows of horizontal vents to connect the drywell to the suppression pool. Instead of a weir annulus, ABWR has 10 vertical vents and 30 horizontal vents (3 horizontal vents per vertical vent). The model for DCD Revision 4 did not properly simulate the horizontal vent portion of the vent system and consequently incorrectly modeled the vent clearing time. These deficiencies are the major contributor to the difference between the previous certified ABWR and the ABWR revised containment analysis results.

The revised ABWR containment analysis correctly models the horizontal vents, and was performed with DCV loss coefficients included. The total DCV loss coefficient is based on a summation of losses. The entrance loss coefficient accounts for the presence of the biological shield wall that is next to the upper drywell entrance to the DCV. The flow loss coefficient accounts for trash racks at the entrance to the vents to block insulation from entering the vents and flowing into the suppression pool. The friction loss through the DCV is the maximum pressure loss coefficient due to piping, cabling and supports routed in the DCV. The exit loss coefficient can be neglected since each DCV is directly above a Drywell-Wetwell (DW-WW) vertical vent. These flow losses are then summed and included in the containment analysis model for the DCV.

The dimensions of the horizontal vents were included in the revised analysis and confirmation of the vent clearing was performed to ensure the revised model was correct.

These modifications were the major contributors to the revised analysis results for the wetwell pressure and drywell-to-wetwell differential pressures.

Additional (Minor) Changes:

The following additional changes are included in the revised ABWR containment analysis.

FWLB flow changes

The FWLB break flow mass and energy from the Balance of Plant (BOP) is the same as shown in the original DCD Figures 6.2-3 and 6.2-4, respectively, except that the initial 3.75-second inventory depletion period has been removed and the assumption of 164% Nuclear Boiler Rated (NBR) flow is used from time zero. This produces a slightly more conservative response to the FWLB.

Suppression Pool Volume

This affects the long-term containment response that uses the Technical Specification Limiting Condition for Operation (LCO) value for minimum suppression pool water level and volume. The water volume in the suppression pool including the vents is required to be equal to or greater than 3,580 cubic meters, as stated in the Tier 1 Section 2.14.1. The ABWR revised containment analyses of scenarios with low initial suppression pool water level were performed with a smaller water volume (3,455 cubic meters) to ensure analysis/operational margin. This smaller volume is based on a suppression pool water level of 6.9 meters. The volume of 3,580 cubic meters is equivalent to a 7-meter water level. The technical specification for suppression pool water level (LCO 3.6.2.2) is greater than or equal to 7 meters and less than or equal to 7.1 meters. This is a very tight band to control the suppression pool water level; so additional margin (0.1 meters) has been built-in to the safety analysis. It is conservative to base the safety analysis for scenarios with a lower initial suppression pool water level based on a smaller water volume as this results in higher pool temperatures.

RHR Heat Exchanger

This affects the long-term containment responses. The RHR overall heat exchanger heat transfer coefficient was increased from $3.7x10^5$ W/°C to $4.27x10^5$ W/°C (approximately 15% increase). The increase was to accommodate the RHR shutdown cooling requirements needed to support the shorter refueling outages that operating plants are achieving. The containment analysis used the larger heat transfer coefficient because this size will be standard for ABWR. Table 6.2.2a has been revised to reflect the increase in the RHR overall heat exchanger heat transfer coefficient.

Wetwell Design Temperature

The certified ABWR wetwell gas space design temperature was 104°C. The containment structural analysis design value is 124°C; therefore the Tier 2 DCD wetwell chamber design temperature was revised to 124°C.

NRC Request for Additional Information 06.02.01.01.C-1, Part 2:

Chapter 6 Change List (25A5675AH), Item 18 (Sec. 6.2.1.1.3.3.1.2) states that the lower drywell flooding is not modeled. Explain why and provide justification for the lower drywell flooding not being modeled.

GEH Response to RAI 06.02.01.01.C-1, Part 2:

As stated in the original DCD text, a portion of the FWLB blowdown break flow is expected to go into the lower drywell which would cause flooding of the lower drywell. During the blowdown period, before initiation of ECCS systems, there is no drawdown of the suppression pool since there is no suction from the suppression pool. Following initiation of ECCS systems, suction from the suppression pool directs suppression pool water to the vessel which is then discharged into the upper drywell through the break after the vessel is reflooded to the height of the break. This water spills to the upper drywell floor which then flows into the drywell entrance to the vertical vent. Most of this cascading water will go to the suppression pool. However, some portion of the water can spill through a DCV connection to the lower drywell. Therefore, after initiation of ECCS vessel injection, with ECCS taking suction from the suppression pool, there can be some transfer of suppression pool water to the lower drywell.

[[

]] In fact, the FWLB break flow water that spills into the lower drywell would be significantly warmer than the suppression pool water. Modeling the hold up of this hot break flow water in the lower drywell due to drywell flooding, instead of modeling transfer of this hot water to the suppression pool (as is modeled for the revised DCD analysis), would produce lower suppression pool temperatures. Consequently, because the revised analysis neglects drywell flooding, and instead assumes all hot break flow water is directed to the suppression pool, the resulting prediction of the pool temperature and containment pressure response is conservative.

A second postulated mechanism for lower drywell flooding with suppression pool drawdown is associated with the potential for reverse vent flow from the suppression pool to the lower drywell through the lower drywell overflow orifice connection to the vertical vent. This would occur if an extended period of large negative drywell-to-wetwell (DW-WW) pressure difference were to occur. However, the ABWR is equipped with wetwell-to-drywell vacuum breakers (VBs) that are designed to mitigate negative drywell-to-wetwell pressure differentials. The VBs are designed to open at the drywell-to-wetwell differential pressure setpoint of -0.5 psid. The results of the limiting negative drywell-to-wetwell differential pressure analyses that are documented in Section 6.2.1.1.4 (and discussed here for RAI Part 7) show that maximum negative DW-WW differential pressures are less than -0.6 psid. These analyses confirmed that the ABWR WW-DW VBs have sufficient capacity to prevent reverse vent water flow from the suppression pool into the lower drywell.

NRC Request for Additional Information 06.02.01.01.C-1, Part 3:

Chapter 6 Change List (25A5675AH), Item 19 (Sec. 6.2.1.1.3.3.1.2) states that the previous assumption is removed and the structure heat sinks are modeled. Provide tables for the structural heat sinks (guidance is provided in Regulatory Guide 1.206 Tables 6-4A through 6-4D). With respect to modeling heat sinks for heat transfer calculations, provide and justify the use of heat transfer coefficient, especially, the condensing heat transfer coefficient or model, and computer mesh spacing used for heat sinks. Justify the steel-concrete interface thermal resistance used for steel-lined concrete heat sinks, as well as the heat transfer correlations used in heat transfer calculations. Provide a configuration control mechanism by which the heat sinks used in analyses will be verified for the as-built plant so that the results from the FSAR analyses can be concluded to be valid for the as-built plant.

Basis for determination of Proprietary Information for GEH Response – NRC RAI 06.02.01.01.C-1, Part 3

The request given by NRC RAI 06.02.01.01.C-1, Part 3 concerns details regarding a number of elements considered by GEH as key to the GEH containment analysis methodology for which containment heat sinks are modeled. As such, release of these details onto the public docket may provide undue advantage to existing or potential competitive methodologies for either benchmarking other analysis methods or outright design basis analysis replacement in updated final safety analysis reports or licensing amendments. Therefore, several details in the following response are marked as GEH Proprietary Information, particularly details related to implementation of heat transfer correlations and parameters for structures exposed to various flow conditions and at the interface between structural materials.

GEH Response to RAI 06.02.01.01.C-1, Part 3:

The heat sink model in the GEH SHEX code is based on [[

]]

Heat sinks applied in the revised DCD [[
]] remain valid for as-built plants unless there is a change in the plant dimensions. However, inputs for heat sinks would be included in the standard form (OPL-4A) that GEH uses to confirm inputs to the containment analysis and confirm validity of the FSAR analysis to the as-built plant.

The following discussion provides details of the heat sink parameters used in the ABWR SHEX code calculations:

Drywell and Wetwell Airspace Heat Sink Heat Transfer

Structural heat sinks are modeled in the drywell airspace, wetwell airspace and suppression pool. Heat transfer in the drywell and wetwell airspace by natural convection and condensation is modeled. The heat transfer mechanism is determined by [[

]]

Natural Convection Heat Transfer

Heat transfer by natural convection uses [[ ]] for either laminar or turbulent flow as warranted by the predicted transient condition. The following heat transfer coefficient relationships are used for heat transfer by natural convection in the drywell and wetwell atmosphere:

For Laminar Flow:

[[

]]

For Turbulent Flow:

[[

]]

Where:

[[

]]

Condensation Heat Transfer

Heat transfer by condensation uses [[

]]

Suppression Pool Heat Sink Heat Transfer

Heat sinks in the suppression pool are also modeled. Heat transfer from the suppression pool water to suppression pool heat sink structures uses the following relationship:

[[ ]]

Where:

[[

]]

Tables 3-2, 3-3 and 3-4 provide heat sink parameters for the modeled heat sinks in the drywell airspace, wetwell airspace and suppression pool respectively.

TABLE 3-1 – [[

]]

[[

]]

TABLE 3-2 DRYWELL HEAT SINK DATA [[

]]

Heat Structure Properties				
Drywell Heat Sink for Metal Structures		**Outside Wall Steel**	**Top Slab Inside Surface Steel**	
[[				
				]]

1) [[ ]]
2) [[

]]

TABLE 3-3 WETWELL AIRSPACE HEAT SINK DATA

Heat Structure Properties				
Wetwell Airspace Heat Sink (Steel)		Outside Wall (steel)	Diaphragm Floor (steel)	Inside wall (steel)
[[				
				]]

1) [[ ]]
2) [[

]]

TABLE 3-4 SUPPRESSION POOL HEAT SINK DATA

Heat Structure Properties				
Suppression Pool Heat Sink (Steel)		Outside Wall Steel	Bottom Surface (steel)	Inside wall (steel)
[[				
				]]

1) [[ ]]
2) [[

]]

NRC Request for Additional Information 06.02.01.01.C-1, Part 4:

Chapter 6 Change List (25A5675AH), Item 23 (Sec. 6.2.1.1.3.3.2) eliminates the wording on instrument delay 0.5 sec. Is the instrument delay included in the 5-sec closing time? Otherwise, justify the removal of the delay.

GEH Response to RAI 06.02.01.01.C-1, Part 4:

The instrument delay of 0.5 seconds to begin closing the MSIVs is included in the total 5.0 second duration for MSIV closure from start of event.

NRC Request for Additional Information 06.02.01.01.C-1, Part 5:

Chapter 6 Change List (25A5675AH), Item 24 (Sec. 6.2.1.1.3.3.2.1) removes the first two assumptions of Sec. 6.2.1.1.3.3.2.1. The original assumption (4) is also removed but not shown in the list. Provide justification for all removals.

GEH Response to RAI 06.02.01.01.C-1, Part 5:

Original Assumption (1) identified the use of the HEM critical breakflow model for the MSLB short-term analysis as an exception to the assumptions identified for the FWLB analysis in Section 6.2.1.1.3.3.1.1. Since use of the HEM critical break flow model for the FWLB is now identified in Section 6.2.1.1.3.3.1.1, and since HEM is also used for the MSLB analysis, it is removed as an exception to the MSLB analysis assumptions.

Original Assumption (2) identified a turbine stop valve closure time of 0.2 seconds that had been originally used to establish the period of steam flow out of the RPV to the turbine before vessel isolation. The revised MSLB analysis assumption for vessel isolation is now given in Assumption (5) in Section 6.2.1.1.3.3.2. The use of the turbine stop valve closure time is not applied for the revised MSLB analysis to establish the vessel isolation time. A turbine trip on high vessel water level (L8) occurring simultaneously with the MSLB would be required for a turbine stop valve closure to occur and control the isolation characteristics for the MSLB which is not applicable to this event.

Original Assumption (3) included assumptions on vessel break flow characteristics and FW injection. The original MSLB analyses for peak drywell temperature assumed steam only breakflow until the vessel water level reaches the main steam line, with an accompanying assumption of FW injection to simulate the vessel water recovery due to FW injection . The revised analysis specifies a two-second time for vessel level swell and therefore a two-second duration for steam only flow. The two second period was selected based on sensitivity studies that showed that peak drywell temperatures occur between 1 and 2 seconds and are therefore unaffected by longer times to vessel level swell. As discussed below for Original Assumption (4), omission of FW injection produces a more conservative MSLB drywell temperature response.

Original Assumption (4) describes the FW injection characteristics to the vessel for the MSLB. For the current short-term MSLB analysis FW injection is not modeled. FW injection to the vessel with relative colder water (relative to the initial vessel water) will tend to reduce the short-term vessel pressure response due to reduced steaming that in turn reduces the break flow to the drywell and consequently reduces the predicted short-term MSLB maximum drywell pressure and temperature. Therefore, to produce a more conservative short-term MSLB pressure and temperature response, FW injection was not included in the MSLB short-term analysis.

NRC Request for Additional Information 06.02.01.01.C-1, Part 6:

Chapter 6 Change List (25A5675AH), Item 26 (Sec. 6.2.1.1.3.3.2.3) indicates that the short-term MSLB (Sec. 6.2.1.1.3.3.2.3) has more severe drywell temperature response than before (i.e. 177.2°C vs. 169.7°C). Explain why and provide justification for such a significant difference.

GEH Response to RAI 06.02.01.01.C-1, Part 6:

The revised analysis included corrections to the vent system modeling that had a significant impact on both the peak drywell pressure and peak drywell temperature. The length of the horizontal vent was not correctly accounted for in the original calculation. In addition, the overall flow loss coefficient for the ABWR vent system did not account for the flow losses associated with the drywell connecting vents (DCV). The corrections that were implemented in the revised calculations produced a delay in clearing of the horizontal vents and an increase in the vent flow resistance after vent clearing. These changes produced the higher values for predicted peak MSLB drywell pressure and temperature.

The peak calculated MSLB drywell temperature of 177.2°C is higher than the design limit of 171.1°C. However, this value represents the peak predicted MSLB drywell atmosphere temperature. A review of the analysis shows that predicted drywell atmosphere temperatures are above 171.1°C for approximately only 1 second during the early, steam break flow only phase of the MSLB. The MSLB analysis assumes level swell of the vessel liquid due to voiding, which produces a two-phase break flow mixture after two seconds into the event. Thereafter, drywell temperatures fall rapidly (see DCD Figure 6.2-13). The very short predicted duration of atmosphere temperature above 171.1°C will not result in drywell structural temperatures that are above the drywell structure design limit.

NRC Request for Additional Information 06.02.01.01.C-1, Part 7:

The negative pressure design evaluation as shown in Sections 6.2.1.1.4.1 and 6.2.1.1.4.2 has significantly changed. Explain why and provide justification for these changes. Provide details regarding how the events are analyzed, including model development, verification and validation, and calculations for audit.

GEH Response to RAI 06.02.01.01.C-1, Part 7:

Analysis Event Modeling

The changes for the revised calculations were implemented to provide a more accurate and realistic simulation of negative pressurization events consistent with the ABWR plant system design, plant system operation and plant operating conditions. The modeling inputs and assumptions for the revised analysis were developed with a bias to produce limiting conservative results with respect to negative drywell-to-wetwell and wetwell-to-Reactor Building differential pressures while simulating events and event conditions that are consistent with the plant design and range of plant operation.

The event description, analysis inputs and analysis assumptions, as well as the basis for assumptions for the revised analysis, are described in detail within the revised DCD text of Section 6.2.1.1.4. The main changes associated with the revised negative pressure design evaluation are as follows:

1. Elimination of analyses for events with inadvertent initiation of containment (drywell/wetwell) spray during normal operation. As identified in the revised text in Section 6.2.1.1.4, the ABWR design and expected operating conditions preclude the possibility of the inadvertent containment spray actuation during normal operation.

2. The revised analyses start at time zero of the postulated LOCA event with normal operating conditions as the initial conditions. The analysis itself is used to predict the initial conditions prior to ECCS reflood or DW spray initiation as opposed to using user defined conditions at the time of ECCS reflood or spray.

3. Drywell break flow rate and breakflow enthalpy during periods of ECCS injection are mechanistically calculated considering the effects of ECCS injection rates, ECCS source temperature, and heatup in the vessel before discharge to the drywell.

4. The revised analyses include modeling of DW spray with suction from the suppression pool. The DW spray temperature is established by the calculated exit temperature of the modeled RHR heat exchanger and accounts for the heat exchanger heat removal characteristics (heat exchanger coefficient), calculated suppression pool temperature, RHR service water temperature and containment spray flow rate.

5. The new analyses include a small steam line break with DW spray operation to provide the containment negative pressure response due to operation of drywell spray in a super-heated steam drywell environment, that would occur during a small steam break, and which is potentially limiting for containment negative pressure.

The results of the revised calculation do show a significantly smaller calculated drywell-to-wetwell negative differential pressure (-3.86 kPaD) relative to the value reported previously of -9.8 kPaD. This difference is mainly attributed to the very conservative approach used in the original DCD analysis to model ECCS reflood for the FWLB with ECCS reflood case. In the original DCD analysis it was assumed that 100% of ECCS flow (including HPCF, LPFL and RCIC) is taken from the CST (at 60°F) and discharged directly into the drywell without heating of the ECCS injection fluid in the vessel.

The revised analysis provides values for peak negative DW-to-Reactor Building (DW-RB) differential pressure (-12.13 kpaD) and peak negative WW-to-Reactor Building (WW-RB) differential pressure (-8.76 kPad). The previous calculation reported only a peak negative WW-to-Reactor Building differential pressure (-11.8 kPaD). These differences are attributed to a change in analysis approach for the revised ABWR DCD calculations. The analysis for ABWR DCD Revision 5 applied the SHEX code to generate transient responses which are then reviewed to determine the peak negative DW-RB differential pressure and peak negative WW-RB differential pressure. The previous analyses used a series of end-point calculations to generate a set of conditions that produces a bounding prediction of the peak negative WW-RB differential pressure.

SHEX Model Application

The GEH SHEX computer code was used for the revised calculations of the ABWR negative containment pressure for ABWR DCD Revision 5. The SHEX code has models for all containment, safety and auxiliary systems needed for the ABWR DCD negative pressure analysis. This is the code that corresponds to the Long-Term Cooling model identified in DCD Section 6.2.1.1.3.4.2. The GEH SHEX code has been verified and validated for general use in compliance with the GEH Nuclear Energy Quality Assurance Program.

The GEH calculations of the ABWR containment negative pressure response with the SHEX code and evidence of verification for the calculations are contained within the GEH electronic archives of the design records.

Impact on DCD:

The DCD, Tier 2, Sections 5.4.7.2.2, 5B.2 and 5B.3, and Table 6.2.2a are revised as shown in the markups provided in Enclosure 3.