ENCLOSURE 2

MFN 03-079

Response to NRC RAI numbers (161, 162, 164, 176, 183, 184, 286, 292, 293, 295, 301, 323, 325, 339, and 382)

Q161. It is stated in Section 3.1.4 (Page 3-4) that "the ESBWR pressure transient does not rapidly increase to a peak value from which it must be rapidly reduced. The pressure increases slowly over several hours…"

Q161.1. What about the peak pressure in the DW immediately after the blowdown, before and after the main horizontal vents are cleared? This peak could be higher than the long term pressure (e.g., Figure 2.7-5 vs. Figure 3.7-2.) Please provide a document discussing this initial peak pressure.

R161.1. The ESBWR containment is designed like a typical pressure suppression containment where the drywell initially pressurizes rapidly (1 to 5 seconds) following a pipe break. [[

]] The pressure then increases slowly, as the remaining noncondensibles are cleared from the drywell. This final containment pressure is determined by the amount of noncondensibles transferred to the wetwell airspace and the vapor pressure.

Q161.2. Clearing of horizontal vents in the main vent lines (PIRT MV3) and chugging (partial opening of the top vent) are potentially important to affect the initial noncondensible gas flow into the WW, and the initial DW pressure peak. Please explain how this issue is handled in the analyses, and list any tests used to validate this model.

R161.2. An extensive set of test data has been obtained over the years for the horizontal vent system for both the Mark III and ABWR containments. [[

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Q162. It is stated in Section 3.1.4 (Page 3-4) that "The containment pressure is determined by the transport of the noncondensible gases into the drywell, not by heat input to the containment." Is this statement true only if the PCCS were 100% efficient? The containment pressure is also affected by the heat not removed by the PCCS, which is deposited in the WW water by condensing steam which was not condensed by PCCS, which, in turn, raises the partial pressure of steam in the WW gas space. Is this long-term deposit of heat into WW the ultimate concern for the ESBWR containment and purpose of various tests and evaluations? Please clarify.

R162. As stated in RAI 161, it is indeed true that the containment pressure is determined by a combination of the noncondensibles pressure and steam vapor pressure. However, [[

]] Consequently, the containment pressure is primarily determined by the noncondensible pressure.

Q164. It is stated that the volumes of drywell were adjusted for "hideout volume" to maximize the effect of noncondensible gas hideout during the blowdown phase of the LOCA.

Q164.1. In Page 3-21, it is stated that the region over the GDCS pools is included in the hideout volume. Since this region is a part of WW, not DW, this seems to be incorrect. Please clarify.

R164.1. The region over the GDCS pools is not part of the DW and is not included in the hideout volume. The statement will be corrected in the next revision of the report.

Q164.2. Please discuss how this hideout volume would affect the initial peak of the DW pressure (adjusting volumes where a large amount of steam is released and compressed should affect the pressure change in the volume.)

R164.2. The initial peak of the DW pressure in the containment analysis is not affected by the modeling of the hideout volume because the total DW volume, including the hideout volume, participates in the pressurization process. The distinguishing feature of the hideout volume is that it retains a higher than average fraction of non-condensable at the end of the initial pressurization transient.

The total DW airspace volume is conserved in the Containment/LOCA analysis. The lower drywell represents the portion of DW below the RPV bottom and is the most significant portion of the hideout volume. The lower drywell is modeled by a one-dimensional component (TEE35, shown in Figure 3.7-1, TRACG Application for ESBWR, NEDC-33083P), which communicates to the bottom of the drywell annulus. This 1-D component participates freely in the pressurization process even though it is labeled as "hideout volume". The 1-D nodalization used in this component effectively retards the short-term mixing of the noncondensible gases in the lower drywell with the discharged steam in the upper drywell.

Q164.3. Immediately after the blowdown, it is possible that some of the DW noncondensible gases can move to the hideout volumes since the pressure in the open space volume is higher than these hideout volumes. Preventing these gases from moving to these volumes, the concept of hideout volumes may result in less noncondensible gases in these volumes than in reality, thus less noncondensible gas available to bleed later. Please discuss if this observation is correct.

R164.3. The observation is incorrect insofar as it presumes the pressure in the open-space volume is higher than in the hideout volume. As discussed in the response to 164.2, the entire drywell volume is pressurized equally but the hideout volume is effectively isolated from the short-term mixing processes that allow most of the noncondensable in the open-space region to be entrained by the blowdown steam and transferred to the wetwell. The TRACG containment analysis shows that the lower drywell (TEE35) retains a large mass fraction of noncondensable at the end of the blowdown. The subsequent gradual release of this noncondensable simulates the effect of hideout on long-term PCCS performance.

Q164.4. On Page 3-22, it is stated that, "This loss coefficient was representative of the loss that would be expected through the restriction area connecting the upper and lower drywell." In view of the potential importance of impact on the PCCS of a small amount of noncondensible gas bleeding, this coefficient may be important. Please explain how this coefficient is determined. Were sensitivity studies performed varying this coefficient?

R164.4. The loss coefficient used in the analyses is based on the restriction area connecting the upper and lower drywell in the ESBWR. This loss coefficient is applied at the TEE35 junction which connects to the bottom of the drywell annulus (VESSEL component).

Sensitivity studies for the SBWR were performed to assess the impact of this loss coefficient on drywell noncondensible gas mass. Calculations of drywell noncondensible gas mass during the first 20 hours of the LOCA, with a zero loss coefficient and a loss coefficient that was twice the value used for the nominal case has a small effect on both the bleed-down rate of drywell noncondensible gas and the calculated pressure.

Q176. Figures 3.7-6 and 3.7-11 show a substantial improvement of PCCS heat removal at about 8 hours. Yet, a substantial amount of noncondensible gases remain in the DW (Figure 3.7-3). Please explain what causes this improvement. The same figures show that the PCCS removes almost 100% of decay heat after 8 hours, yet the containment pressure continues to increase. What is the cause of this pressure increase?

R176. Figures 3.7-6 and 3.7-11 compare the total heat removal by the PCCS with the decay heat. Figure 3.7-6 shows that the total heat removal capacity increases from [[ ]] This increase is the result of a reduction of the noncondensable fraction in the inlet flow to the PCCS. The PCCS takes steam/gas mixture from the upper half of the DW, and Figure 3.7-3 shows that the amount of noncondensible gases in this region is significantly reduced during this time period.

After 8 hours the PCCs are able to remove the DW heat load with some margin to spare. From 8 to 48 hours, the containment pressure continues to increase due to the purging of the noncondensible gases from the lower half of the DW into the WW. During this time period, the noncondensable fraction in the inlet mixture is small and does not prevent the PCCS from removing the entire decay heat load. The DW pressure reaches the maximum value when all noncondensible gases are purged from the DW into the WW.

Q183. Page 2-2 - It seems that "2.2 Analysis of Events" should include two additional events – bottom drain line break (BDLB) and inadvertent automatic depressurization system (ADS). The BDLB is the only break located below the core and leads to the slowest RPV depressurization compared to the MSLB and the GDLB (break at the downcomer annulus above the core). These three LOCAs are expected to bracket other LOCAs in terms of the break sizes, locations, and fluid conditions upstream of the break. TRACG calculations for BDLB are therefore desirable and should cover 72 hours of the transient. Containment response to the BDLB should also be included, because the break flow at such a low elevation is likely to sweep nitrogen gas from the lower DW to the WW and reduce the likelihood of later release of noncondensible gas to PCCS condensers to degrade their performance. As a result, BDLB may provide a lower bound on the containment pressure during the long-term PCCS cooling phase.

R183. The analysis reported in the TRACG Application for ESBWR (NEDC 33083P), includes representative breaks and failures. The SSAR will include a complete set of calculations to cover all breaks and single failures to determine the limiting breaks and single failures for the final design. See also response to RAI 184 on the discussion of the inadvertent ADS actuation event.

The calculations submitted in the Application report (NEDC 33083P) have focused on the early stages of the plant response (about 2000 seconds) because during this time period the plant is undergoing transient changes like vessel depressurization and water injection from the GDCS. The long-term response (up to 72 hours) is dependent on the long-term equilibrium distribution of the different water inventories (See response to RAI 323.5). Since these inventories are expected to be dependent on the final design to be included in the SSAR, the long-term response of the vessel might be slightly different in the SSAR. However, the attached results show the plant response to the BDL break for the current reference design for the longer time period.
This case shows that there is no core heatup for the entire BDLB transient. The core is covered and remains covered by more than 3 meters of 2-phase mixture after the injection of suppression pool water into the RPV via the equalization lines.

This case assumed a single failure of 1 GDCS injection valve, and used the base case conditions as described in Section 3.7.2 in the ESBWR Application Report (NEDC-33083P). Reactor scram was initiated on Level 3 trip, and reactor power started to shutdown after an appropriate delay time.

Figure 183-1 shows the long-term pressure response. Following the postulated LOCA, the drywell pressure increased rapidly leading to clearing of the PCC and main vents. The DW pressure reaches the first peak with a value of [[ ]] The pressure decreases when the GDCS starts flowing at about [[ ]] seconds. Vacuum breaker openings occur as the steam production drops off. The GDCS pools are completely drained in about 2 hours.

Subsequently, decay heat overcomes the subcooling of the GDCS water, and steaming resumes. The drywell pressure increases and reaches a 2nd peak with a value of [[ ]] The long-term DW pressure is significantly lower than that for the MSLB case due to the additional GDCS draindown volume, which is about 2 times larger than that for the MSLB case.

Figure 183-2 compares the two-phase levels in the RPV Chimney, RPV downcomer, Drywell Annulus and Suppression Pool. For the first [[ ]], the RPV continues to lose water inventory to the DW annulus via the BDL break. Consequently, the RPV water levels drop and the water level in the DW annulus rises. At [[ ]] after the break, the water from the GDCS pools and the RPV fill the DW annulus to about [[ ]] The chimney and downcomer levels reach the minimum value of about 7 meters. At this minimum value, the chimney two-phase level drops [[ ]] At this minimum 2-phase level, the core is still covered with two-phase mixture with adequate cooling. No core heatup was calculated for the entire BDLB transient.

From 6 to 16 hours, BDL break flow reverses direction. A small amount of water flows from the DW annulus into the RPV. The DW annulus level drops slightly with the RPV levels rise accordingly in this period. At [[ ]] water starts to flow into the RPV from the suppression pool via the equalization lines. The levels in the RPV and DW annulus increase as the results of the initial and subsequent water injections. The water levels reach equilibrium conditions after [[ ]] following the break. For long-term (from [[ ]]), the core is covered by more than 3 meters of 2-phase mixture. The pressure dips (Figure 183-1) slightly each time there is significant addition of cold water to the RPV (at about [[ ]]

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Q184. The rationale for selecting the inadvertent ADS actuation event is that it cannot be bracketed by MSLB during the "early" blowdown phase from the initial opening of the safety relief valves (SRVs) to the opening of the depressurization valves (DPVs), because there is no PCCS heat removal until the DPVs are opened. A TRACG calculation for inadvertent ADS actuation is therefore desirable and should last until the transient becomes similar to any LOCAs. Please provide the opening sequence including time delay for the SRVs and DPVs in the inadvertent ADS.

R184. The opening time sequence of the SRV's and DPV's was given in RAI 23. Inadvertent ADS actuation has not been considered as an initiating event for typical accident analysis, but is an event considered in the PRA realm. Inadvertent ADS is beyond the scope of the analysis performed in Chapter 15 and will be covered in Chapter 19 of the Safety Analysis Report.

Q286. Provide the derivation of the system equations in Section 7. Specifically, there is a large portion of the transient in which the RPV and the containment interact dynamically. Where are the equations for this system of at least 2-volumes and several connecting paths? How do the PI values compare between equations and between facilities and prototype?

R286. In the ESBWR there is minimal interaction between the different regions of the ESBWR. We do not believe that a coupled equation with a multiple volume system and flow paths is necessary. The results of test programs and global momentum scaling performed as part of the SBWR program (and documented in the Scaling of the SBWR Related Tests) has supported this conclusion. A brief summary is provided below.

A good indication of possible interactions between system elements is the existence of similar time constants in adjacent system elements. When there is a large difference in time constants for adjacent system regions there is little dynamic interaction between the system elements and resulting in a decoupling of the systems. This concept has been discussed by Zuber in *Hierarchical, Two-Tiered Scaling Analysis, Appendix D to An Integrated Structure and Scaling Methodology for Severe Accident Technical Issue Resolution* where he discusses hierarchical decomposition of systems and the associated differences in time constants.

In the ESBWR there is strong separation in the time constants of adjacent systems. This is typical of pressure suppression systems where the large thermal mass of the suppression pool results in a very long time constant for the wetwell. This minimizes dynamic interactions between the WW and other parts of the system as demonstrated by the stable pressure behavior of the WW in the ESBWR predictions and long-term test results.

There is a short period at the beginning of an accident (when the noncondensible gas is moving from the DW to the WW) when the time constants of the RPV and containment volumes are similar. This is because pressure suppression is not effective at mitigating the effect of noncondensible gas moving to the WW. However, during this time the flow from the RPV is choked decoupling it from the containment, anyhow. This has been discussed in the response to RAI 294.

The PCC has a very short time constant so the PCC pressure rapidly adjusts to the pressure of the DW, which has a much longer time constant, without interactions between their pressures. Similarly the startup times for the connecting pipes in the ESBWR are very short so the pipe flows also reach a quasi steady value based on the pressures in the volumes that they connect.

One possibility for interactions is through the parallel flow paths from the RPV and DW to the WW during the early phases of an accident. This was investigated quantitatively in the SBWR scaling report, *Scaling of the SBWR Related Tests*, NEDC-32288P. In that report a global momentum method was applied to look at the various volumes and flow paths as an integral system. A set of matrix equations representing the multiple flow paths and volumes was set up and evaluated during different temporal phases. The results of that work are reported in Section 4 of the report. The exercise found that interactions between different flow paths and volumes were negligible.

Q292. The acceptance criterion presented in the report for a well-scaled facility is meaningless unless one can relate the effect of such distortion range on the figure of merit. If the figure of merit is core coolability, it is necessary to show that when a given non-dimensional group is within the acceptability range, its effect on core coolability is within the acceptable range of uncertainties. Describe what figure of merit is used and provide a detailed justification on the acceptance criterion based on the impact that the distortions of important parameters have on the figure of merit.

R292. The tests are not intended to be prototype tests that will predict actual peak values in the figures of merit (RPV water level and containment pressure). Instead they are used to provide data to qualify the TRACG code so that it can be used to predict the plant response for a wide range of accidents. As such the magnitudes of the processes present in the test should be similar to those expected in the plant so that the TRACG models can be qualified for predicting those processes. This puts a requirement on the magnitude of the processes present in test and plant (we chose 1/3 to 3 criterion) but it does not place any specific requirements on variations in the figure of merit. In addition the dominant processes should be the same in the tests and ESBWR. Clearly certain break points in test and plant behavior, such as core uncovery versus no core uncovery should be avoided, however.

The 1/3 – 3 criterion was selected to make sure that the phenomena of interest were of the same order of magnitude in the ESBWR and tests. The range 1/3 to 3 results in a total variation of a factor of 9 between the largest and smallest parameter, or approximately 1 order of magnitude. The factor of 3 in either direction also provides separation between the range used to identify phenomena as unimportant. Processes that are a factor of 10 less than the dominant process are considered unimportant.

Q293. With reference to the discussion concerning the relationship between pressure and inventory, Figure 8-5 shows excellent agreement in the temporal behavior of the pressure. This result should be directly related to the liquid inventory information depicted in Figure 8-2. Here, during the crucial GDCS phase, the liquid mass results do not appear to be consistent: Giraffe/SIT exhibits three times the magnitude of liquid mass as ESBWR and GIST about one third. Explain why this is an acceptable outcome.

R293. As discussed in the response to RAI 292, the purpose of the tests is to provide data for TRACG qualification so that TRACG can predict the plant response. To satisfy this goal, the test must include the important processes at a similar magnitude to the ESBWR. Since a factor of three difference is the criterion used to satisfy this, it should be expected that the rate of change for a figure of merit could also be different by a factor of three, or so. This should be acceptable also. Additionally, since the two tests mentioned cover the range of 1/3 to 3, they bound the ESBWR conditions.

In the case of the GDCS flow mentioned above, the fact that the vessels fill faster or slower is of little importance. In fact, when the GDCS flows begin in earnest they dominate all other processes. This becomes a simple filling problem. Since the process is dominated by a single parameter, it would be possible to use an alternate time scaling for this phase (i.e. not 1:1) and end up with the GDCS flow parameters scaled very closely.

Q295. Matching the pressure traces in time has some relevance to the overall plant behavior. However, the discrepancies in the RPV liquid inventory recovery are more significant. How can these concluding remarks be tied to the overall discussion on the acceptable range of the distortions outlined in Section 8 of the report?

R295. As stated in RAI responses 292 and 293, the rates of change for figures of merit can be expected to be different by as much as a factor of three, since this is the criterion used for the individual processes. If is not necessary to match the figures of merit any closer than this as discussed in those responses.

Q301. In Table 3.4-1 of NEDC-33083P, PIRT phenomena MV1 and MV3 are identified as "Long-term response insensitive," based on Reference 24, "TRACG Qualification for SBWR," NEDC-32725P, Rev. 1 , Vol 2, Section 5.5, September 1997. Is the vent system (pipe length, submergence, flow area, etc.) similar to the SBWR design tested at the Pressure Suppression Test Facility? If not, provided a justification for the values used in the TRACG ESBWR model.

R301. Both the SBWR and the ESBWR use identical vent systems. The PSTF geometry tested for the Mark III containment is similar to that in the ESBWR. Please refer to RAI 323.8 for further details and discussion. The SBWR vent system was not tested at the Pressure Suppression Test Facility (PSTF).

Q323. For the ECCS LOCA case, in Section 2.6.1 of TRACG application, it is stated that "Drywell model set to minimize containment pressurization rate." In Section 3.1.4 (Page 3-3), it is indicated that a conservative application approach for containment analysis has been used to model MSLB LOCA containment behavior. GE also pointed out that the TRACG code is not designed to accurately predict containment phenomenon. Specific application procedures are used to apply TRACG to this specific design and different procedures are used to evaluate ECCS and containment responses. Please address the following questions for ECCS LOCA and containment LOCA analysis:

ECCS/LOCA

Q323.1. Does the minimized containment pressurization rate provide a conservative gravity driven cooling system (GDCS) line injection timing and minimum water level prediction? Please explain why.

R323.1. GDCS line injection begins when the combination of the containment (wetwell) pressure and the static head in the GDCS pool is greater than the vessel pressure. [[

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Q323.2. List all other detailed modeling procedures and practices to minimize the containment pressurization rate and provide justifications.

R323.2. The major modeling procedure to minimize the containment pressurization rate is [[

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Q323.3. In particular, please explain how the wetwell (WW) and drywell (DW) are partitioned into different radial and axial cells and what criteria are used to establish the cell face boundary?

R323.3. The rationale for the nodalization of the SBWR containment model is described in [[

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Q323.4. The TRACG physics package is mainly developed based on small and confined space test data. This package has been used to calculate the WW pool condensation, thermal and interfacial heat transfer between the noncondensible gas and WW pool water. Can this physics package provide a conservative two-phase water level in the shroud with the given nodalization?

R323.4. The TRACG models for containment modeling have been discussed at length in responses to RAIs [[

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Q323.5. Due to the TRACG ECCS/LOCA model containment radial distortion, the staff is not convinced that the distribution of steam and noncondensible gas calculated by the ECCS/LOCA model is inaccurate. Please explain how the long term cooling through passive containment cooling system (PCCS) was affected and why the current application procedure can lead to a conservative minimum water level prediction at about 10 to 11 hours into the transient.

R323.5. The long term minimum water level is determined primarily by [[

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Q323.6. For the same reason, have other parts of the containment (WW, GDCS Pool, PCCS) model been set to minimize the prediction of the two-phase water level above the core? If so, please provide detailed modeling procedures and justifications.

R323.6. See the response above for the final equilibrium level reached.

Q323.7. Have the DW to WW vents been modeled in the same way for ECCS /LOCA as for containment/LOCA? If not, please explain why.

R323.7. [[

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CONTAINMENT/LOCA

Q323.8. It is stated that a special modeling approach has been used to model WW and DW to WW vents to conservatively calculate the WW temperature and pressure response. This approach appears to be developed based on the TRACG model nodalization for the pressure suppression test facility (PSTF) test. Please explain why the similar nodalization can produce conservative response even though the PSTF geometry dimensions appear to be different from that of the ESBWR WW.

R323.8. [[

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Q325. What computer code was used to calculate decay heat and core void effects? Has that code been previously reviewed by staff? If so, please provide any relevant references.

R325. The decay heat model for transients and for LOCA evaluations is the same as the model reviewed and approved for SAFER-GESTR (NEDE-23785 Vol. III Appendix B), with the following improvements:

- The decay heat from fission products has been updated from the ANSI/ANS-5.1-1979 standard to the 1994 standard
- The fuel cycle parameters (enrichment, exposure, ect.) were conservative, bounding values rather than nominal values
- Because conservative values were used for the fuel cycle parameters in place of nominal values, the uncertainty terms associated with the nominal values were eliminated, leaving the basic two-sigma data uncertainty from the standard
- New, more conservative evaluations of miscellaneous Actinides and structural activation products provide additional heat

Q339. Please provide Paul Sherrer Institute (PSI) document ALPHA-703-0, "PANDA P-Series Test Specification," Dec. 5, 1997. Is there a PSI/TEPSS document comparing pretest predictions with PANDA P-series tests? If so, please provide the document. (Note that on ALPHA-716-0/Page13 for Test P1, it is stated that the global DW/WW pressure response of test data was as expected from pretest calculations.)

R339. Since these tests were used as additional data for TRACG qualification, the key reports were the results, which were provided. The reports readily available to GE on the Panda P series tests have been provided in the ESBWR Test Report NEDC-33081, Rev 0. All the References were not available to GE but attached is the final version of the Test Specification.

The pretest predictions that were done for the program were documented in the attached Reference - "Technology Enhancement for Passive Safety Systems - TEPSS: Final Report", INNO-TEPSS(99)-D20, European Commission, Fourth Framework Programme on Nuclear Fission Safety, Contract FI4I-CT95-0008. Since these tests were used as additional data for the qualification of TRACG after the tests were run, the pre-test predictions were of limited interest.

Q382. Pages 2-103 (3rd paragraph) and 2-109 (Fig. 2.5-3). [[

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Q382.1. Does GE agree or disagree with this comment? Give us a reason for disagreement.

R382.1. GE does disagree with the comment.

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1 The ESBWR design pressure is 60 psia. GE recognizes that inconsistencies exist in the ESBWR Design Description Report, NEDC-33084P, and this will be rectified in the next revision of that report

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Q382.2. [[

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R382.2. The direct gas sampling results from the GIRAFFE/He tests were successful, and reported in NEDC-32608P, "GIRAFFE SBWR Helium Series Test Report", Tables 6.1 through 6.6. This document was provided to the NRC via MFN-091-96 dated June 24, 1996. The data is again provided below for reference.

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