ENCLOSURE 2

MFN 03-070

Response to NRC RAI numbers (13, 14, 28-30, 33, 34, 36-44, 46, 49-53, 55, 57-59, 61-64, 66, 68, 69, 72-76, 78, 80, 81, 83-85, 88, 93, 96, 98, 99, 102-104, 107, 108, 110-112, 147-150, 153-158, 163, 165, 166, 168-175, 178-182, 185, 186, 188, 189, 192-194, 196-201, 203-212, 215-219, 221-224, 226-230, 233, 235, 237-256, 263, 265, 267-270, 273, 274, 278, 280, 283-285, 287-289, 291, 300, 302, 303, 318, 320, 322, 328, 332, 340-344, 348, 361, 362, 364-370, 377, 386, 407, 409-413)

Q13. Test facility insulation / Heat Losses :

Tests were performed at prototypical temperature and pressure; whereas, test pressure vessel walls were thinner than the actual vessel wall thickness. As a result, heat losses through the vessel wall in the tests are expected to be higher than the prototype, and can result in systematic distortions of test data. The impact and safety significance of distortions needs to be related to the degree of importance of the distorted phenomena. In the Scaling report, there was no discussion presented on the distortions due to heat losses, especially in the GIRAFFE facility testings, where the primary variable of interest is the water level in the reactor pressure vessel (RPV). The staff, therefore, requests that General Electric (GE) assess the impact of heat loss on test data obtained from the facilities, such as GIRAFFE, and explain what was done to offset this potential source of distortion when qualifying the TRACG code.

R13. The effects of RPV heat losses in the GIRAFFE/SIT and GIST tests were assessed in the SBWR Scaling Report (NEDC-32288P, Rev 1). The results for these tests can be found in Tables 4.1-11 and 4.1-14 of that report. The analyses found that the heat losses in the SBWR and GIST were negligible while the heat losses in GIRAFFE were on the order of 6% of the decay heat for the late blowdown and GDCS transition phases. The resulting distortion in the overall heat input is small as indicated by the similar values of Π_q for SBWR and the test facilities given in the referenced tables. Therefore the safety significance of the distortions is very small on two counts: 1) the total contribution of the heat losses to the depressurization rate is small; and 2) the distortion in the total sensible energy term, as denoted by Π_q, is also small. As would be expected, the distortion in the sensible energy term, Π_q, is 6%, the same as the decay heat loss.

Because the effects of heat losses were found to be small in the SBWR analyses, the heat losses were grouped together with the decay heat term in the current analyses and report rather than retaining them as separate terms. The effect of the heat losses is still contained in the combined term so heat losses are factored into the assessment of heat loss scaling distortions. See response to RAI 230 for TRACG response.

Q14. Surface-to-Volume ratio of PCC headers :
In the 2nd paragraph, page 8-5 of the Scaling report (NEDC-33082P), it was stated that because the surface area to volume ratio is increased for the reduced length headers of the passive containment cooling system (PCCS) in the testing facilities (PANDA, PANTHERS), the heat removal through the header walls was increased. The staff realizes that the heat loss in the headers is much less compared to that through the tube walls. However, a higher heat loss through the headers results in increased total heat removal capacity for the PCCS in the tests (non-conservative effect), and this may have an impact on the containment pressure. The staff, therefore, requests that GE provide an estimate as to how a distortion in PCCS heat removal capacity will impact the peak containment pressure.

R14. The additional heat loss through the headers does not have a significant effect on the containment pressure. As noted in Section 7.6 of the ESBWR Scaling Report, the total capacity of the PCC is only important during periods where the demand for heat removal is greater than the maximum capacity of the PCC. For all other periods the PCCs will self regulate to the demand level. An example is given in Figure 14-1 which is the base case TRACG prediction for the ESBWR main steam line break (previously presented as Figure 3.7-6 in NEDC-33083P). Figure 14-1 illustrates that the heat removal demand is greater than the PCC's ability to remove heat for approximately the first eight hours. It is during this interval that increased surface area (i.e. a larger header) would provide additional benefit. Beyond eight hours the PCC has excess heat removal capacity and self-regulates to match the decay heat load. Therefore excess capacity in the header has no influence on the PCC heat removal or the system behavior. To quantify the impact of excess heat removal capability in the PCC, sensitivity cases were performed using TRACG with excess heat removal capacity through the PCC header.

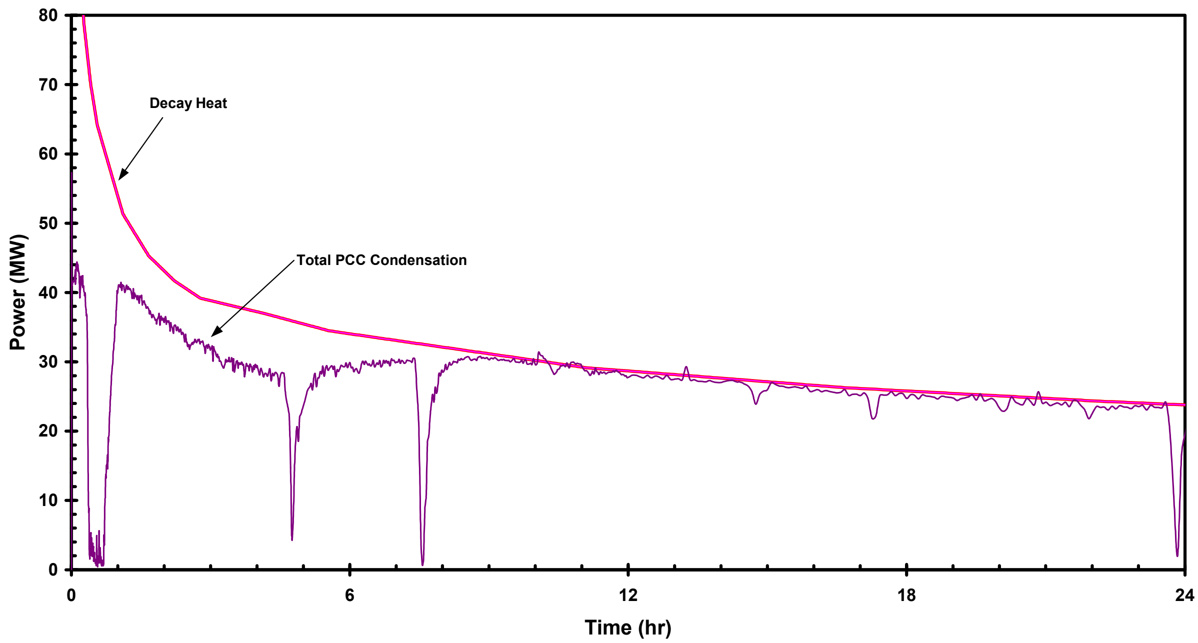

Figure 14-1 PCC and Decay heat Power for Base Case

The header heat losses were addressed in detail in the bottom-up scaling results presented in the SBWR scaling report (NEDC-32288P, Rev 1). [[

]] The larger heat loss in PANDA is primarily due to the fact that the surface area of the header endplates is approximately full scale while the number of tubes is scaled to 1:25 of the SBWR. [[

]]

Two TRACG cases were considered for this analysis. The first case modeled a PCC with no header surface area. [[

]] The increased PCC capacity results in a WW pressure decrease. [[

]] As expected, the change in PCC surface area is manifested in small changes in the suppression pool temperature and consequently the wetwell pressure during the first 8 hours, when the decay heat exceeds the PCC heat removal capability. [[

]]
[[

Figure 14-2 Comparison of Suppression Pool Surface Temperatures for Different PCC Header Heat Losses

Figure 14-3 Comparison of Wetwell Pressure for Different PCC Header Heat Losses

]]

Q28. The passive containment cooling system (PCCS) performance depends on the pressure difference between drywell (DW) and wetwell (WW) and not having any other path than the PCCS (the only path between them being through the PCCS). A GDCSLB with a single failure of the check valve can potentially create bypass between DW and WW, and compromise the PCCS performance. Please explain why this is not considered or why this is not possible.

R28. Please refer to the simplified system schematic (figure 28.1), which shows that the GDCS suction line is placed in a long, vertical sump that extends several meters below the bottom elevation of the GDCS Pool. The GDCS sump is formed from a heavy-walled stainless steel pipe that runs adjacent to the outer bounding wall of the suppression pool and is structurally supported from this wall. The GDCS injection piping in this region reaches downward to the sump bottom but maintains an appropriate clearance such that inordinate flow entry losses are avoided. The depth and diameter of the sump are selected to ensure that the necessary residual inventory of water to maintain the loop seal intact and functioning is always present throughout the post-LOCA period.

If the GDCS injection line to the vessel were to break at a non-conservative location and the biased open check valve failed, water would siphon out of that GDCS pool, flooding the lower drywell as designed. The water in the suction line sump would only drain down to the level of the lowest pipe break elevation, leaving water in the sump to provide a seal sufficient to prevent bypass flow from the drywell to wetwell or vice-versa.

ESBWR Gravity-Driven Cooling System - Simplified Schematic Diagram

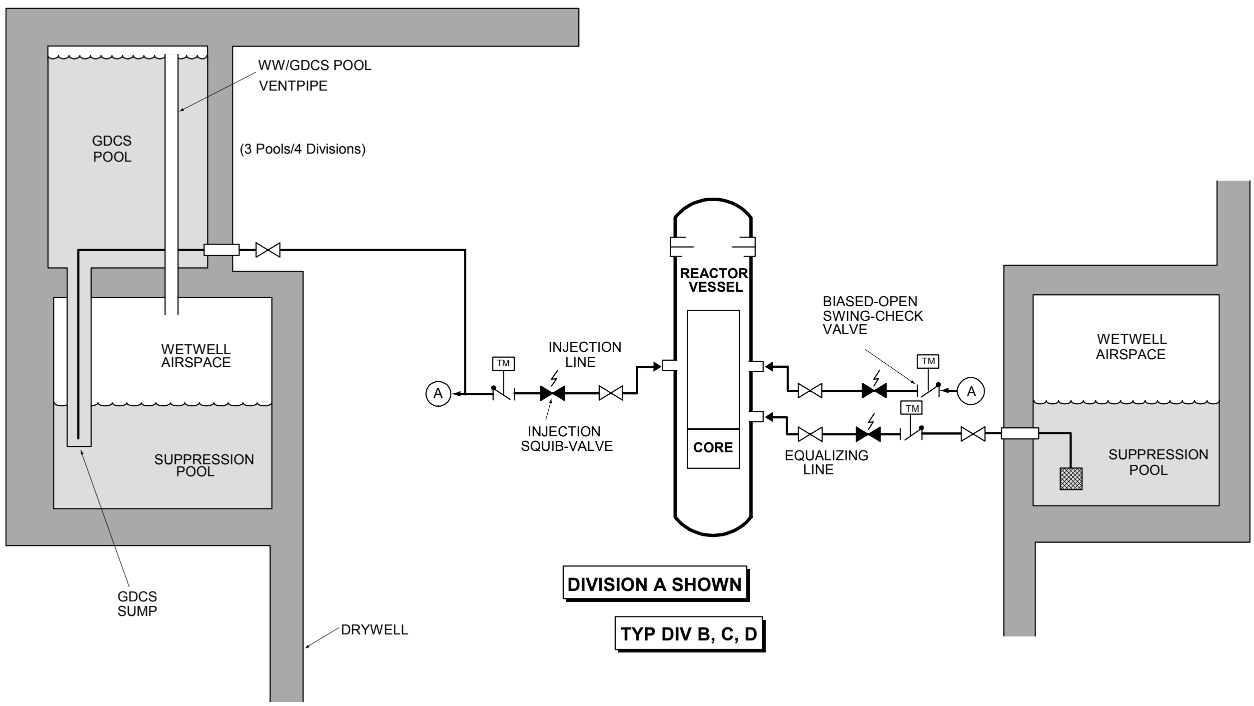

Figure28.1

Q29. What are possible single failure criteria? Should the failure of vacuum breaker (VB) be considered as a single failure? If not, please explain why not.

R29. The failure of one out of the three vacuum breakers could be considered highly unlikely (based on an extensive test program) however there is a remote possibility that it would fail and then it would be considered as a single failure if it did not close. This possibility exists but the vacuum breakers are backed up with a manually controlled valve that can close the inlet to any vacuum breaker determined to be open or not fully closed. Refer to Section 3.3.7.3 of Document NEDC-33079P, "Test and Analysis Program Description"

Q30. Section 3.6, NEDC-33083P, states that a bounding calculation was performed with conservative values of all parameters and initial conditions. Were there any studies performed that the combination of the worst values would generate the conservative results?

R30. There were no specific studies performed to show that the combination of the worst values would generate the conservative results for ESBWR. However, results from previous studies for SBWR suggested that this approach would generate conservative results.

Uncertainty analysis was performed for the SBWR containment (NEDE-32178P, Sect. 4.3.2) with 59 TRACG trial runs. In these studies, specific uncertainties were defined for a total of [[ ]] The difference in the peak containment pressures (results from 72 hours), that is the difference between the highest calculated value in 59 runs and the calculated value with base case conditions (delta containment pressure), is about [[ ]]

The magnitudes of uncertainties and individual perturbations are similar between the SBWR and the ESBWR. It is reasonable to expect that if an uncertainty analysis (59 trial runs) were performed using the full set of 24 TRACG inputs for the ESBWR the calculated delta containment pressure would be comparable to that for the SBWR.

For the ESBWR, a bounding calculation was performed with the combination of the worst values of all operating plant parameters and 6 significant model parameters (a subset of those used in the SBWR 59 trial runs). The difference in the peak containment pressures (delta containment pressure) between the bounding case and the base case is [[ ]] (NEDC-33083P, TRACG Application for ESBWR, Sect. 3.7.3). The ESBWR approach generates delta containment pressure that is [[ ]] than that is calculated by 59 trial runs for the SBWR. Hence, the calculated value is acceptable.

Q33. Please provide a roadmap for separate effects testing used for TRACG qualification for containment analysis.

R33. **Separate Effects Tests for Containment Applications**
[[

]]

Q34. What are "k" and "B" in Eq. 3.2-8 and how are they specified?

R34. k [[

]] It is defined in the nomenclature in Section 3.1.1 and Section 6.1.7.3. B_s is defined in the nomenclature in Section 3.1.1. [[

]]

Q35. Section 3.3 - When values of solution from the balance equations are restricted by critical flow or counter current flow limit (CCFL), is the time step repeated with smaller time, or are flows adjusted and calculation proceeds?

R35. The velocity is set to the [[ ]] The critical flow model is described in Section 6.3 and the CCFL is described in Section 6.1.7.2.

Q36. Equation 4.1-5 - The heat transfer coefficients for different phases are multiplied by the same surface area. During the boiling regime, the surface will either have liquid or vapor in contact but not both. Please explain why this has been done or correct the equations. Same question for Eq. 4.2-1.

R36. The flow regime map is described in Section 5. and the wall heat transfer is described in Section 6.6. If liquid is in contact with the wall as in single phase liquid convection or nucleate boiling, [[ ]] If vapor is in contact with the wall as in single phase vapor convection or film boiling, [[ ]] as described in Section 6.6.8. Also see the response for Q58.

Q37. Is there guidance on when to use the implicit or explicit option for conduction calculation?

R37. [[ ]] calculations. See page 21 of the TRACG02A User's Manual (NEDC-32956P).

Q38. Equation 5.1-4 is used for developing criterion for transition from bubbly to annular flows. The equation implies that volume flux is much larger than 1 m/s. What happens during low flow conditions?

R38. The assumption is made (TRACG02) that [[ ]] This is true for most practical BWR applications. For example in a BWR fuel bundle the volumetric flux for rated conditions range from [[ ]] m/sec., while the drift flux velocity range from [[ ]] m/sec. For low flow such as natural circulation the volumetric flux range from [[ ]] However, the excellent comparison to void fraction data shown in NEDE-32177P demonstrates the applicability of the model. For TRACG04 the assumption that the drift velocity can be neglected is not made. This modification will be documented in Revision 3 of the TRACG Model LTR.

Q39. Equation 5.1-20 - How is E_1 defined?

R39. As it is stated in the line just below: "where [[ ]] given by Equation 5.1-17…" The nomenclature is confusing. [[ ]] The confusing nomenclature will be clarified in Revision 3 of the TRACG Model LTR.

Q40. Based on Fig 5.1-3, Ishii's original model is as good as the modified one. Why is there a need to modify it?

R40. The reason is given in the first paragraph of Section 5.1.2.2 just before Equation 5.1-17: [["

]]

Q41. Table 6.0-1 addresses the question of applicability of TRACG for a vessel. However, TRACG is also used for containment modeling. Is there a similar table for containment?

R41. Yes, containment components are included in Table 6.0-1 in NEDE-32176, Revision 1. These are not documented in Rev. 2 since the NRC was not asked to review the containment model for the AOO applications. The documentation for the containment components will be included in Revision 3 of the TRACG Model LTR.

Q42. Why doesn't Table 6.0-1 include a steam separator?

R42. The separator models and the range of assessment are described in Section 7.7. Note in particular Figures 7.7-3 to 7.7-7. The omission of the separator from Table 6.0-1 will be corrected in Revision 3 of the TRACG Model LTR.

Q43. Interpretation of terms for Eq. 6.1-5, provides a definition for α. The same symbol is used for more than one purpose. What is the basis that these symbols are identical?

R43. [[

]] The assumption however was adopted for all flow regimes for consistency. The excellent comparison to void fraction data shown in NEDE-32177P (Section 3.1) demonstrates the applicability of the model.

Q44. Please provide a comparison between Eq. 3.1-30 and 6.1-2. Why do the gravity terms have different signs?

R44. Different sign conventions were used in the two sections. In Section 3, the acceleration of gravity is –9.81m/sec^2 for vertical up-flow. Section 6.1, which was extracted from Reference 6.1-2 uses the opposite sign convention where the acceleration of gravity is 9.81m/sec^2 for vertical up-flow. This discrepancy will be corrected in the next revision of the report.

Q46. Equation6.1-10 - The 'g' term (gravity) is missing.

R46. This is a typographical error, 'g' is missing in the last term of Equation 6.1-10. Down-stream applications of the equation correctly include the 'g' term. This will be corrected in the next revision of the report.

Q49. Below Eq. 6.1-63, there is reference to Eq. 5.1-25. Where is this equation?

R49. This reference should be to Equation 5.1-23. This will be corrected in the next revision of the report.

Q50. What is the basis of Eq. 6.1-63?

R50. [[

]] Equation 6.1-63 is chosen as a simple formulation which has the right limits.

The virtual mass term accounts for the fact that the relative velocity on which the interfacial force depends can vary with time. The term is introduced on page 3.1-5. It is represented in the simplified momentum expressions in Eqs. (3.1-10,11,30,31) by f_{VM}. It is correlated as indicated in Eq. (3.2-9).

Q51. Section 6.2.2.3 - What void fraction is used to apportion the wall friction between the phases? Is it upstream cell or an average between the cells?

R51. Section 6.2.2.3 refers to the form losses. [[ ]] is used to partition the form losses. The [[ ]] is also used to partition the wall friction between the phases. See Section 6.2.1.1.

Q52. Section 6.4 - Is a numerically explicit approach used for implementing the level tracking model?

R52. The movement of two-phase levels is [[ ]]

Q53. Section 6.5.3 - Are the interfacial area densities implied in interfacial momentum transfer (6.1.3) and used in mass transfer the same?

R53. [[ ]] is used for the interfacial heat and mass transfer. [[ ]] is used for the interfacial shear between the phases.

Q55. Section 6.5.4.1 (annular flow regime) - How is the noncondensible gas concentration estimated at the interface? The saturation temperature will depend on this concentration.

R55. The [[ ]] is used, however, for condensation a degradation of the condensation due to the local accumulation of noncondensible gas at the interface is correlated in the factor C_{ncg} as described at the end of Section 6.5.4.1..

Q57. Please check Eq. 6.5-29. When pipe is half full and α=0.5, does this expression reduce to the correct limit?

R57. Equation 6.5-29 is based on the following assumptions. [[

]] Figure 57-1 shows the void fraction, the surface area per unit volume assuming a smooth surface, the surface area per unit volume assuming a wavy surface and Equation 6.5-29 as function of the liquid height.

[[

]]

Figure 57-1 Surface Area for Stratified Flow

[[

]]

Q58. Section 6.6 describes the heat transfer coefficient at the wall. In section 3.1, Eqs. 3.1-19 and 3.1-20 indicate that the heat transfer coefficient accounts for the fraction of the wall in contact with one or the other phase. However, heat transfer coefficients in Section 6.6 do not indicate this. Please explain.

R58. The logic for the selection of the heat transfer coefficients is given Section 6.6.2 and shown in Table 6.6.1. This Table is repeated here for convenience.

Table 6.6.1 Selection Logic for Wall Heat Transfer

[[

]]

[[

]]

[[ ]] (6.6-37)

where

[[ ]] (6.6-38)

and:

$h_{NB}(T_{CHF})$ = Nucleate boiling heat transfer coefficient evaluated at T_{CHF}

$h_{FB}(T_{min})$ = Film boiling heat transfer coefficient evaluated at T_{min}.

In Equation 6.6-37, the first term is heat transfer to the liquid and the second term is heat transfer to the vapor. This equation could therefore be expressed as:

[[ ]] (6.6-37a)

and

[[ ]] (6.6-37b)

Q59. Section 6.6.10.3 - The applicability of the Tien-Gonzalez correlation was based on CORECOOL code. Was there any assessment done with TRACG?

R59. Functional testing was done for correct implementation. Qualification was not done for the TRACG AOO submittal as [[

]] Qualification has been performed and will be included for the TRACG LOCA submittal.

Q61. Equation 6.6-64 - What is "Rem" and where is it defined?

R61. The definition for Re_m was inadvertently missed. [[

[[ ]]

]]

Q62. Equation6.6-65 - How is "ρ_m" defined?

R62. The density of the gas mixture (ρ_m) is the [[
]]

Q63. Equation 6.6-68 - What effect does "$f_{1,other}$" cover ?

R63. According to Section 3.6 of [[

]]

Q64. Section 6.6.11 - Lighter than steam (helium) or heavier than steam (air) have different flow near the interface and may affect the film thickness differently. Where is this effect considered?

R64. The factor [[

]]Other mechanisms not explicitly considered will be reflected in the degradation factors [[

]]

Q66. Section 7.7 - The high void core region in the steam separator is assumed to have solid body rotation and the liquid film will also have swirl with tangential velocity decreasing towards the wall (no slip). Please explain the basis of liquid film tangential velocity described in Eq. 7.7-2.

R66. [[

]]

Q68. Section 7.5.2 (p. 7.5-10 to 7.5-18) - Are there specific references for the development of the various correlations and the associated parameters, such as Eqs. 7.5-9, 7.5-13, 7.5-15, 7.5-16?

R68. There are many questions on the dynamic gap model. This model has been extensively reviewed previously and is already approved by the NRC. The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs (Ref. NEDE-23785-PA, Vol. 1 and 2). The reference number is [7.5-4].

Q69. Section 7.5.2.2 (p. 7.5-12) - What is the physical significance of the effective hot radial thermal gap R_{eff}?

R69. See Eqs. (7.5-21) and (7.5-22). [[

]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q72. Section 7.5.2.2 (p. 7.5-13) - Do the constants in Eq. 7.5-14 depend on the relative mix of steam and hydrogen?

R72. [[

]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q73. Section 7.5.2.3 (p. 7.5-15) - The section on fuel pellet gap conductance has defined several "gaps." Which 'hot gap size' does the model refer to in relation to the calculation of the contact pressure P_c?

R73. [[
]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q74. Section 7.5.2.4 (p. 7.5-16) - What is the basis for the constant in Eq. 7.5-24?

R74. [[

]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q75. Section 7.5.2.5 (p. 7.5-16) - Does R_{ref} vary with time and how?

R75. [[

]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q76. Section 7.5.2.5 (p. 7.5-16) - How does the thermal expansion coefficient of the fuel take into consideration the effects of burnup, such as densification and relocation?

R76. The effects of burnup [[ ]] See the response for Q75.

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q78. Section 7.5.2.6.2 (p. 7.5-18) - Does Eq. 7.5-30 still apply if P_{ci} is less than zero?

R78. [[ ]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q80. Section 7.5.3.2 (p. 7.5-19) - Does the cladding perforation model apply only to the core location of maximum linear heat generation rate (LHGR)?

R80. The perforation model applies to any point along the fuel rod. Normally perforation would be expected to occur at the point of peak LHGR, but perforation could occur for an LHGR less than the PLHGR, if the temperature is higher at that location.

Q81. Section 7.5.3.1 (p. 7.5-19) - Why does subscript 'f' refers to two different variables in Eqs. 7.5-33 and 7.5-34?

R81. [[

]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q83. Section 7.5.3.1 (p. 7.5-20) - How is the factor determined for Eq. 7.5-36?

R83. [[

]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q84. Section 7.5.3.2 (p. 7.5-20) - What are the subscripts 'g', 'l' and 'v', 'w', and 'pl' in Eqs. 7.5-37 to 7.5-39?

R84. The subscripts in question are defined as follows:

"g" and "v" - vapor outside of clad,
"l" - liquid outside of clad,
"w" - unheated cladding,
"pl" - plenum.

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q85. Section 7.5.3.2 (p. 7.5-20) - Is the gas temperature in the fuel the same as the plenum gas temperature?

R85. No, the volume to temperature ratio in the fuel column is determined using Eq. (7.5-35).

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q88. Section 7.9 - Is a heat exchanger component used for ICS and PCCS modeling?

R88. The ICS and PCCS heat exchangers are modeled using the standard PIPE and TEE components coupled with the component to component heat transfer models. Condensation heat transfer is given by the models described in Section 6.6.11.

Q93. Section 3.1.4 (p. 3-18) - The inlet quality for the chimney section was determined by mass and energy balance. Did the energy balance take into consideration that a fraction of the fission energy was not deposited in the core?

R93. In a typical BWR approximately [[ ]] of the energy is deposited in the fuel rods. The remaining energy is deposited directly in the water in the fuel channel and in the bypass between the fuel channels. Since the flow in the chimney is the sum of the in channel and bypass flow, it does not matter where the energy is deposited.

Q96. Section 3.2.1 (p.3-36) - Is there any reason the negative temperature deviation is so much higher in Figure 3.2-3 than the other 3 comparisons?

R96. In test 3.06.6B the peak temperature was approximately [[ ]] higher at the 3.6m elevation than at the 2.4m elevation. TRACG predicted this trend for both tests. However in test 3.08.6C the test showed a peak temperature that was approximately [[ ]] less at the 3.6m elevation than at the 2.4m elevation. There is no apparent reason for this difference in the observed trend.

Q98. Section 3.3.2 (p. 3-43) - In Figure 3.3-2, the legends for the data points are missing.

R98. The legends for the data points are shown in the attached Figure 3.10-1.

[[

Figure 3.10-1. CSHT Facility CCFL Test Data

]]

Q99. Section 3.4.1.2 (p. 3-48) - The axial temperature profiles are shown in Figure 3.4-5 and not in Section 3.4-5.

R99. This will be corrected in the next revision.

Q102. Section 3.4.1.5 (p. 3-56) - In Figure 3.4-8, what is the cause of the 20 second delay in the TRACG prediction of the transition to pure steam flow?

R102. For test 24 the measured break flow is [[ ]] for the liquid blow down phase and [[ ]] for the two-phase blow down phase. This is shown in Table 3.4-2. As a result of this difference the two-phase level drops down to the break location earlier in the test than in the calculation.

Q103. Section 3.4.2 (p. 3-59) - What is the cause of the flow spikes predicted by TRACG in Figures 3.4-11 through 3.4-13?

R103. In PSTF test 5801-15 the two-phase level [[ ]] This is evident from a comparison of Figures 3.1-17 and 3.1-22. [[ ]] seen in Figure 3.4-11. The initial spike in the break flow seen in Figures 3.4-12 and 3.4-13 is the [[ ]] This period correspond to the initial fast depressurization seen in Figures 3.1-23 and 3.1-25. The [[ ]]

Q104. Section 3.5 (p. 3-64) - Where is the documentation for the TRACG qualification of the pressure drop for the core bypass flow paths?

R104. TRACG uses loss coefficients for the leakage paths based on experimental data. These data were obtained for operating BWRs, but the dominant leakage paths should be similar for the ESBWR. The models for the leakage and bypass flow paths are described in NEDE-32785-1-PA. Also, see Section 7.5.1 of NEDE-32176P, Rev. 2 and Reference 7.5-1 that it cites.

Q107. Section 3.6.3 (p.3-72) - Are there any TRACG qualifications for burnout prediction under low pressure, low flow, and near saturation conditions that are expected in a LOCA for the ESBWR?

R107. For the FIST small break LOCA test, the dryout occurs for low flow and low pressure conditions. See Section 5.2.3. For the TLTA boil off test, the dryout occurs for low flow and low pressure. See Section 5.1.1.

Q108. Section 5.1.1 (p. 5-1) - The boiloff test was conducted at a pressure of 2.76 MPa. Has there been assessment of low pressure boiloff that would be more representative of ESBWR post-LOCA conditions?

R108. Integral tests such as GIST and GIRAFFE/SIT show no boiling transition at low pressures. The Zuber correlation used under these conditions has a wide pressure data base.

Q110. Section 5.1.1.3 (p. 5-4) - Figures 5.1-3 to 5.1-6 showed the comparison between measured and calculated void fraction. How are the weighted average void fractions derived from the calculated nodal void fractions?

R110. The weighted average void fraction is the sum of the node length multiplied with the void fraction over the distance between the measurement locations divided by the sum of the node lengths. Thus the weighted average void fraction represents the average void fraction between the measurement locations.

Q111. Section 5.1.1.4 (p. 5-4) - What is the sensitivity of the calculated results to TRACG nodalization?

R111. No nodalization studies were done for this test. The nodalization strategy is derived from sensitivity studies on separate effects tests.

Q112. Section 5.1.3.3 (p. 5-37) - Was TRACG able to calculate the lower plenum bulk flashing at about 16 sec. after the uncovery of the recirculation line suction inlet?

R112. Yes, this is clearly seen in Figure 5.1-36

Q147. Section 2.3.2 (p. 2-47) - Tables 2.3-2 through 2.3-5 did not show any test that assessed the PIRT high ranked phenomenon C23, core pressure drop. Was the assessment done as part of other PIRT phenomena?

R147. [[

]]

Q148. Table 2.3-4 (p. 2-54) - What is the reason for introducing a new PIRT phenomenon C26 in this table? Should the interest be for the critical power for a 10-ft core and not a 9-ft one?

R148. [[

]]

Q149. Section 2.4.4.1 (p. 2-66) - The collapsed level is a measure of liquid inventory, and is the product of mixture level and the liquid fraction. How could the sensitivity to the calculated void fraction be removed when the collapsed rather than the mixture two-phase level is used as the figure of merit to characterize water level above the core in a transient?

R149. [[

]]

Q150. Table 2.4-1 (p. 2-69) - According to Table 2.4-1, burnout correlation, PIRT parameter C13, is a high ranked phenomenon. Why wasn't C13 identified in Table 2.4-3 for sensitivity study? Is the modified-Zuber critical heat flux (CHF) correlation one of the options available for channel component in TRACG?

R150. C13 was not identified in Table 2.4-3 because all TRACG calculations show that the core is covered with two-phase mixture for all cases. No core heatup was calculated due to local critical heat flux.

TRACG evaluates boiling transition with the [[ ]] for the CHAN component.

A sensitivity study has subsequently been performed on the Zuber correlation. A multiplier of 0.8 was applied to account for a 20% uncertainty. No core heatup was calculated.

Q153. Section 2.4.4.2 (Figure 2.4-13) - Why is it that for some PIRT parameters, e.g. PIRT05 and PIRT84, only positive deviation is observed for both the lower and upper bound values? What is the implication of this deviation to the selection of conservative bounding values for the PIRT parameters? Are the responses of the chimney collapsed level to the uncertainties in the PIRT parameters consistent with the expected behavior of the two-phase system?

R153. [[

]]

Q154. Section 2.4.4.2 (Figures 2.4-13 and 2.4-14) - The sensitivity studies looked at the responses of the collapsed level and the peak cladding temperature (PCT) to the uncertainties in the PIRT parameters. Figures 2.4-13 and 2.4-14 show that in response to uncertainty in a given PIRT parameter the deviations in collapsed level and PCT do not always go in the same direction (see e.g. PIRT84M and PIRT84P). What is the correspondence between uncertainties in the collapsed level and the PCT? 10 CFR 50.46 defines 5 acceptance criteria for ECCS. How does the chimney collapsed level relate to these 5 acceptance criteria?

R154. The ESBWR design is such that there is no core uncovery during any LOCA scenario (i.e. the chimney collapsed level is always above the top of the core). Under this situation, the PCTs are directly proportional to the differences in liquid saturation temperature corresponding to the slight differences in maximum pressure reached before ADS, and are on the order of 1° K. Hence ,there is no correlation between the sensitivities in the chimney collapsed level and the PCT.
The 10CFR50.46 criteria are satisfied because the PCT is well below 2200 F. In the absence of any core heatup, the criteria related to PCT, maximum local oxidation, maximum hydrogen generation, coolable geometry and long term cooling are automatically satisfied. The minimum chimney collapsed level criterion is an additional design margin that GE has proposed above and beyond the requirements of 10CFR50.46.

Q155. Section 2.6 (p. 2-91) - Is it possible in the TRACG calculation to predict a dryout condition in one of the core channels while a two-phase level exists in the chimney? A likely situation when this might happen is when the core flow is low. The modified-Zuber critical heat flux (CHF) correlation is inversely proportional to the void fraction and its value can be much lower than the pool boiling CHF. What is the minimum critical power ratio (CPR) in the bounding base and the sensitivity calculations?

R155. [[

]]

Q156. Section 2.6.1 (p. 2-91) - What is the basis for determining the 2σ uncertainty level of the static head in the chimney?

R156. [[

]]

Q157. Section 2.7.1.1 (p. 2-92) - The TRACG nodalization of the ESBWR RPV and containment for ECCS/LOCA analysis was shown in Figure 2.7-1. Where is the suction point of the GDCS? Is there any possibility of draining the GDCS pool through the broken GDCS line creating a bypass flow path between the drywell and wetwell? Was this confirmed by an qualififcation tests?

R157. Please refer to the response to RAI 28 for a description of the GDCS pool and suction line. The loop seal design principle has been confirmed in other integrated tests but for the GDCS line break and GDCS suction line draining, no qualification test was deemed necessary.

Q158. Section 2.7.2.2 (p. 2-101) - Some of the sensitivity cases have suggested that the net effect of combining uncertainties at the extreme values may not be synergistic. A case in point is the result shown in Figure 2.5-1 where the chimney collapsed level responded in opposite directions to uncertainties in plant parameters individually and when combined. Could there be compensating effects? Are the results of the 'bounding' case bounding? Which case has the lower minimum chimney collapsed level, the 'bounding case' or sensitivity case PIRT57-P shown in Figure 2.4-13?

R158. Please refer to response to Q153 for the discussions of compensating effects and adequacy of the 'bounding' approach. The 'bounding case' has the lower minimum chimney collapsed level than the sensitivity case PIRT57-P, about 0.31 m lower.

Q163. Modeling of WW gas space stratification in Section 3.3.1.1.2 referred to the PANDA modeling experience for basis of having "restricted mixing between layers," which "produced conservative results for PANDA and is expected to be conservative for ESBWR."

Q163.1. The PANDA report (NEDC-33080P) does not mention this particular modeling. The PANDA report says in Section 2.6.2.10 that "post-test evaluation of P-series tests demonstrated that TRACG conservatively calculates heatup of the WW gas space." However, PANDA modeling does not use the "restricted mixing between layers." Please explain.

R163.1. [[

]]

Q163.2. PANDA results show substantially different trends for the WW gas temperature between the test and analyses for all tests, although the magnitudes are similar. This difference may be magnified in the long-term (PANDA usually ran about 10 hours, while the time period of interest in ESBWR is 72 hours.) Please discuss how the difference in trends is concluded to be conservative.

R163.2. [[

]]

Q165. In Tables 3.3-3 and 3.3-4, some of the highly ranked phenomena are not cross-marked for any tests. Please discuss how these phenomena are validated or qualified for TRACG.

R165. A composite of Tables 3.3-2, 3.3-3 and 3.3-4 (see TAPD, NEDC-33079P) shows that the following highly ranked containment phenomena do not have test coverage:
[[

]]

Q166. How is the nodalization accounted for in the bias calculations?

R166. [[

]]

Q168. On Page 3-37 (MV1), it is stated that "In Section 5.5 of Reference 24, the short-term peak drywell pressure is shown to be always conservatively overpredicted by TRACG." Please provide a summary discussion of that finding.

R168. [[

]]

Q169. On page 3-40 (PC1), the bias in k/A^2 was determined "assuming the same values for ρ_{mix} and m_{mix}." However, these values are not constants through the PCCS tubes, due to condensation, since the Δp in the equation is overall pressure drop in the PCCS, ρ_{mix} and m_{mix} should be some kind of average in the tubes, which requires some knowledge of how much steam is condensed along the tubes. Please explain how ρ_{mix} and m_{mix} are determined in the evaluation of the bias of k/A^2.

R169. [[

]]

Q170. With respect to PC2 (Page 3-40), the potential degradation of condensation in the PCCS tubes due to continuous bleeding of a small amount of noncondensible gas in a long period may be the single most important issue in the ESBWR containment performance. Yet the documents reviewed do not provide any specific information regarding the degree of degradation. Are there any studies (tests and analyses) showing the degrees of degradation as a function of concentration (and perhaps flow rates) of noncondensible gas in the tubes? Are there any such tests available where a small amount of noncondensible gas (in the order of 1%) is continuously injected to the DW?

R170. [[

]]

Q171. Initial DW and WW temperatures were set at their operating limit, i.e, 110°F (P. 3-49, Section 3.5.2.1). However, the higher initial temperature may results in less noncondensible gas inventory and, thus, may not be conservative. Please discuss this aspect.

R171. Lowering the initial DW and WW temperatures will increase the noncondensible gas inventory.

The long-term DW pressure depends on the amount of noncondensible gas inventory, the suppression pool surface temperature, and the WW temperature. Lowering the initial suppression pool temperature (to be consistent with the initial WW temperature) would reduce the transient WW temperature and suppression pool surface temperature. The DW pressure reduction due to these two factors is more than that by the increased noncondensible gas inventory.

Q172. Table 3.5-1 shows that the bounding value of the suppression pool level is higher than the nominal value. While it may be conservative in terms of the WW gas space available in the later stage of the accident, it may not be conservative in terms of the water inventory above the PCCS vent outlet, which is available to be heated by the uncondensed steam in the bounding calculations. It will also require a higher Δp (DW-WW) to clear the PCCS vent to the WW pool. Please explain.

R172. The impact of 5 cm higher initial suppression pool level on the surface temperature is expected to be small.

Figures 3.7-7 (Base Case) and 3.7-12 (Bounding Case) (NEDC-33083P, TRACG Application for ESBWR) show the suppression pool temperature responses. These figures show that (a) [[ ]] of the temperature rises in the top 3 levels (Levels 4, 5 and 6) of the suppression pool occurs during the [[ ]] of the transient, and (b) Levels 4, 5 and 6 are well mixed at the end of this period due to steam flow from the top horizontal vents and PCC vent flow. The PCC vent flow (steam + air) reduces significantly after this time period. From [[ ]] the PCC vent flow contains essential only air and no significant amount of energy is added to the top layer of the suppression pool.

Uncertainty analysis was performed for the SBWR containment (NEDE-32178P, Sect. 4.3.2) with 59 TRACG trial runs. In these studies, the suppression pool level was varied over a range of 10 cm. A positive correlation coefficient indicated [[ ]] so overall conservative. The slightly higher ΔP (DW-WW) to clear the PCCS vent to the WW pool shows no significant impact on the peak containment pressure.

Q173. Table 3.5-1 shows that the bounding value of the GDCS pool level is higher than the nominal value. While it may be conservative in terms of the WW gas space available in the later stage of the accident, it may not be conservative in terms of the total water inventory available to cool the reactor. Please explain.

R173. The increased GDCS water volume due to higher initial GDCS pool level is less than 1%, and is expected to have insignificant impact on the reactor cooling.

TRACG calculations show that the core is covered with two-phase mixture for all cases and no core heatup was calculated. The chimney water level recovers shortly after the start of the GDCS flow and the minimum water level does not depend on the amount of GDCS water volume.

Q174. Section 3.7.2 refers to Figure 2.7-5 for the short term response. However, Figure 2.7-5 presents the result of a GDCS line break, while Section 3.7.2 discusses Main Steam line break. Please clarify.

R174. Yes, it is an error to refer Figure 2.7-5 for the discussion in Section 3.7.2. The phrase "(For the short term response (2000 s), see Figure 2.7-5)" should be deleted from the 3rd paragraph in Section 3.7.2.

Q175. Figure 3.7-2 shows periodic drops of containment pressure. Please explain whether they are real or numerical and what causes them, and evaluate the impact of these phenomena on the eventual containment pressure.

R175. The periodic drops of containment pressure are caused by periodic flows of GDCS cold water into the RPV. This phenomenon has no impact on the eventual containment pressure.

Figure 3.7-5 (NEDC-33083P) shows the level in the two GDCS pools. The level in the pools reaches an equilibrium with the RPV downcomer level, which is at the elevation of the steamline. After reaching an equilibrium level, the RPV level drops slowly due to boil-off, and the pressure difference between the RPV and the WW (same as the GDCS air space) reduces slowly as the decay heat decreases. At some time later, the GDCS driving head (GDCS pool pressure + the static head) becomes greater than that for the RPV, and allowing cold GDCS water to flow into the RPV. This sudden addition of cold water into the RPV reduces the steam production. As shown in Figure 3.7-6, the sharp dips in the heat removal indicate periods where the PCC heat removal exceeded the RPV steam production, resulting a drop in the drywell pressure below the wetwell pressure. Subsequently the vacuum breakers open, some noncondensibles are returned to the drywell. The GDCS flow stops shortly after the vacuum breaker opening due to lower GDCS driving head and increased RPV water level. Following the vacuum breaker opening and the stop of GDCS flow, steam production is resumed in the RPV and restores some pressure difference between the RPV and the DW and WW. The GDCS and RPV levels reach another equilibrium at this time.

These periodic drops of containment pressure and opening of vacuum breakers occur several times during the 72 hours transients. Each time some noncondensibles are returned to the drywell. During the period between the periodic drops, these noncondensibles are pushed back into the wetwell by the PCC action. The eventual containment pressure can be determined when all noncondensibles have been pushed into the wetwell, and are not impacted by these periodic drops of containment pressure.

Q178. Page xv - For LASL, it is suggested to add a statement in parentheses for clarification. [Los Alamos National Laboratory (LANL) is the current name for LASL].

R178. This change will be made in the next revision of the document.

Q179. Page A-122 - In Table A.5-3, the TRACG analyses for PANDA P-Series tests focus entirely on containment phenomena*, as confirmed by the information presented in "TRACG Qualification for ESBWR" (NEDC-33080P). We understand that with the exception of P2 test*, the focus of these PANDA tests is on the long-term cooling containment issues. However, the PANDA P-Series tests are the only ESBWR tests in which the gas space of the gravity driven cooling system (GDCS) pool was connected to the wetwell (WW) gas space. As a result, please revise Table A.5-3 and "TRACG Qualification for ESBWR" to include the vessel parameters such as reactor pressure vessel (RPV) pressure and water level in the data comparison. In addition, other containment parameters such as suppression pool (SP) water level and drywell (DW) water level (from wall condensation) should also be included.

*One exception is that the reactor pressure vessel (RPV) and GDCS water levels were included in data comparison for the PANDA P2 test, which covered the long-term passive containment cooling system (PCCS) cooling phase and the transition from GDCS injection to the long-term cooling phase.

R179. [[

]]

Q180. Page A-70 - Provide a comparison of the important vessel and containment parameters (such as RPV water level, pressures of RPV and DW and WW, SP level, and GDCS pool level) of the three integral counterpart tests.

R180. Please see the response to question 336.

Q181. Page 1-10 (1st paragraph) - GIST test data have been used in the qualification of TRACG to SBWR and documented in Reference 15 (the GIST report, GEFR-00850, October 1989). As shown in Figs. 4.3-51, 4.3-53, and 4.3-54 of GEFR-00850, the GDCS flow rate predicted by TRACG is good for main steam line break (MSLB - GIST Test B01), acceptable for the GDCS Line Break (GDLB - GIST Test C01A), but poor for the bottom drain line break (BDLB - GIST Test A07 for which the TRACG-calculated total GDCS flow is about half of the data). In comparison, better agreement with GIST data was achieved in the TRACG04A calculations shown in Fig. 5.1-21, Fig. 5.1-23, and Fig. 5.1-12 of "TRACG Qualification for SBWR" (NEDC-32725P, Vol. 2). What are the major differences (in terms of models, code input, and noding) between TRACG04A and the earlier version of TRACG used for the GIST calculations (GEFR-00850)?

R181. [[

]]

Q182. Page 1-8, Section1.2.1.3.4 states that "Key model parameters and input variables will be treated conservatively to produce a bounding calculation of the containment parameters of interest (pressure and temperature)." Provide a narrative describing the basis for the decision reached to use conservative as opposed to best-estimate values for key model parameters.

R182. This statement applies to containment analysis. The Qualification Report provides the basis for this approach. TRACG, in conjunction with the coarse noding used for containment analysis, cannot accurately calculate phenomena such as suppression pool stratification and noncondensible mixing and transport in the drywell. Hence, a conservative approach is employed.

Q185. In section 2.2.1, the statement is made that "The limiting LOCA ... from the viewpoint of containment pressure, it is likely to be the large steamline break." This statement appears equivocal. Why is the statement not more definitive if the analysis is available?

R185. The steamline break has been shown to be the most limiting break for containment pressure. The statement in the TAPD will be changed to a definitive statement in the next revision of the document.

Q186. Page 2-3, Section 2.2.1.1 - The statement is made that, "This setpoint [level 3] is assumed to scram the reactor." Will the level scram setpoint be reached before the drywell pressure scram setpoint?

R186. [[

]]

Q188. In the ESBWR design, how was the relative and absolute submergence of the PCCS vent and the upper most main vent determined?

R188. [[

]]

Q189. Page2-8, Section 2.2.1.4 - *Long-Term PCCS Period* - The statement is made that, "However, unlike the GDCS line break, the steam generated by the decay heat is condensed and all of it is returned to the vessel via the PCCS Drainage Tank." Why should the two scenarios differ in this regard?

R189. [[

]]

Q192. Page 2-13 - Main Steam Isolation Valve (MSIV) Closure Transient - Is this discussion consistent with the scenario in the licensing calculations?

R192. The scenario is based on realistic calculations for the MSIV closure ATWS event. The licensing scenario may incorporate conservatisms to bound uncertainties, but is not expected to be significantly different.

Q193. Page 2-15, Section 2.2.4.4 - While geysering can indeed be “postulated,” its actual relevance to the ESBWR is not entirely evident. Is there analysis that would show that it should indeed be considered?

R193. [[

]]

Q194. Page 2-16 - There is a discussion of the conditions for opening the GDCS equalizing lines (between the SP and RPV). (1) Are there any integral test data (e.g., GIRAFFE) that covered PCCS performance after the opening of equalizing lines (to drain SP water into the RPV as expected during GDLB or BDLB)? (2) Is there an analysis or physical evidence to ensure that any manometric oscillation between the connected SP and RPV will not occur or it will not uncover an equalizing line (if the check valve on the equalizing line fails to close when called upon)?

R194. [[

]]

Q196. Page 2-21, Fig. 2-2-5 - The figure shows that the TRACG-calculated PCCS heat removal rate is always lower than the core decay heat power for the MSLB. On page A-8, it is stated that under certain conditions, the PCCS heat removal rate can exceed the core decay power. Are there any TRACG LOCA analyses or integral test data in which the PCCS heat removal rate exceeded decay power for a certain period of time?

R196. The decay heat is higher than the PCC heat removal because of other heat sinks, such as drywell walls. The common mode of the PCCS is to remove the energy required to balance the net energy input. In scenarios leading to VB openings, heat removal by the PCCS exceeds the net energy input until the drywell pressure drops below the VB setpoint.

Q197. Page 2-22 - Is there a TRACG analysis for an ATWS initiated by inadvertent MSIV closure for the ESBWR (similar to Fig. 2.2-6 obtained for SBWR)?

R197. [[

]]

Q198. Page 2-24 - (1) Provide the reference from which the ESBWR stability map in Fig. 2.2-7 was obtained. (2) Was this figure based on ODYSY computer code calculations? (3) Describe the ESBWR transients represented by the small elliptic area (in the lower left corner of Fig. 2.2-7). (4) If control rods are fully inserted, is there any possibility for the reactor to enter the unstable region shown in this figure?

R198. 1) The stability map shown is a BWR map and is used for assessing margins in operating BWRs [Ref. BWROG Program Option E1A; Also, *ODYSY Application for Stability Licensing Calculations*, NEDC-32992P-A, July 2001]. The design boundary for the ESBWR uses decay ratios that are half of the BWR design limits to provide sufficient margins during normal operation. These values are consistent with decay ratios in the flow control operating range for jet pump BWRs.

2) [[

]]

3) The elliptic region in the box represents Dodewaard data , and the other ellipse characterizes the estimated range of ESBWR steady state operation. No transient evaluations have been performed as yet for the ESBWR. Two transient scenarios were evaluated for the SBWR and the results shown in the SBWR TAPD (NEDC-32391P, Rev.C).

4) If all rods are fully inserted, the reactor will be at hot shutdown and there is no possibility of entering the unstable region on the map.

Q199. Page 2-25 - Is there a power/flow stability map for ESBWR (similar to Fig. 2.2-8 obtained for SBWR)?

R199. [[

]]

Q200. Page 2-27, Section 2.3 - In many instances, aspects of plant design that may be termed initial and boundary conditions are as important to the analysis as phenomena/processes. While such items are not to be considered part of TRACG qualification, they become part of transient analysis and may be explored in experimental programs. How and at what stage are the relevant aspects of initial and boundary conditions considered vis a vis the phenomena identification and ranking table (PIRT)? Is this aspect considered to be covered by the Bottom-Up process?

R200. [[

]]

Q201. Question was addressed in July 9, 2003, meeting.

R201. No Response Required.

Q203. Page 2-49 - It seems that some high-ranked phenomena are missing in Table 2.3-4 (ESBWR PIRT for ATWS), because it does not include any phenomena associated with standby liquid control system (SLCS) which can play an important role in ATWS. For example, the Bottom-Up Process listed in Table 3.2-1 (p. 3-9) has identified two high-ranked SLCS phenomena (Issues C41/1 and C41/2) that are missing in Table 2.3-4. Please explain why Table 2.3-4 does not include these SLCS phenomena.

R203. FMCRD availability is not considered for ATWS events. Availability of the FMCRDs will mitigate the event similar to a normal scram. [[

]]

Q204. Page 2-54, Table 2.3-6 - Should this list include the controllers for feedwater and steam pressure valves?

R204. Control systems are considered in overall plant stability evaluations, but do not influence stability because the time constants are an order of magnitude larger than those for density wave oscillations. Typically, control systems are tuned for optimal performance during plant startup.

Q205. Question was addressed in July 9, 2003, meeting.

R205. No Response Required.

Q206. Page 3-3, Table 3.2-1 - There is a typographical error – "hutdown" should be replaced with "shutdown."

R206. The typo will be corrected in the next revision of the document.

Q207. Page 3-5 - Please explain why the following phenomena are not ranked high (7 or higher) in the Bottom-Up Process listed in Table 3.2-1 (ESBWR Thermal-Hydraulic Phenomena): (1) Issue No. J/3 - Unique power/flow operating map and natural circulation characteristics, (2) Issue N21/3 - Effect of core inlet subcooling on stability, (3) Issue T10/3 - WW response to long-term heat addition from PCCS vents (Note that a companion issue, Issue T10/5 - Stratification below PCCS vent discharge, is ranked high), (4) Issue T10/9 - Establishes DW to WW pressure drop and PCCS operation**,** (5) Issue T10/12 - PCCS submergence determines DW to WW, and (6) Issue T15/11 - Replaces drywell GDCS pool. (Note that the explanation for Issue J/3 on p. 3-22 (3.3.6.3 Natural Circulation Characteristics) seems to indicate its importance, because extensive TRACG qualification against test data was conducted on this issue.)

R207. [[

]]

Q208. Page 3-5 - There are several questions regarding Table 3.2-1. (1) Please explain the footnote "ESBWR T/H phenomena outlined in gray have not been evaluated. Relative importance was < 5 or phenomena not unique to ESBWR or the system was not safety related." Note that some of the phenomena outlined in gray are ranked high. (2) Why is Issue B11/11 (carryover/carryunder at lower limit of AS2B test data) an ESBWR-unique phenomenon? What does AS2B stand for? (3) For Issue B11/14 (Bypass leakage), should ATWS be included under "Kind/Phase of Transient"? (4) For Issue B21/3 (break flow of DPV stub tubes), why it is not listed as an ESBWR-unique thermal-hydraulic phenomenon? (5) For Issue C12/2 (Loss of control rod drive system (CRDS) flow), please explain the logic that CRDS pumps trip if GDCS pool level drops by a specified amount. What is C&FWS (not in Abbreviations and Acronyms)? (6) For Issue C41/1, it seems that bulk temperature must be maintained no less than 68 ^{o}F (instead of "less than 68 ^{o}F") to prevent precipitation. (7) For Issue E50/3, should "Interaction between DW pressure, RPV pressure" be replaced with "Interaction between WW pressure, RPV pressure" under the "Important T/H Phenomena" column?

R208. [[

]]

Q209. Page 3-18 (last line) - It is stated, "Additional information on ESBWR core stability can be found in Subsection 3.3.7 under Stability and Natural Circulation Characteristics." But Subsection 3.3.7 is for containment phenomena. As a result, should this statement be modified?

R209. The reference should refer to Section 3.3.6. This will be corrected in the next revision of the report.

Q210. Page 3-19, Section 3.3.1.3 - Since core uncovery does not occur, what is the relevance of the section covering flow distribution in the chimney during reflood?

R210. Flow distribution in the chimney during reflood is not important. This issue is rated important for normal operation and stability. The discussion on Page 3-19 will be modified as follows:

[[

]]

This change will be made in the next revision of the report.

Q211. Page 3-20, Section 3.3.3.5 - The statement is made that "Analysis clearly demonstrates that it is not possible to produce a sufficient pressure difference between the RPV Isolation Condenser drain line nozzle and the DPV for this to happen." Does the analysis refer to TRACG (page 4-24, 4.4.4) or some other method?

R211. The analysis refers to the TRACG calculations on Page 4-24 and Appendix B.

Q212. Page 3-22 - The following statement is made: "A related issue is that of "soft" vs. "hard" inlet conditions." Does this refer to the natural circulation flow loop as opposed to one with pumped flow?

R212. Yes, flow configurations with pumped flow are referred to as those with hard inlet conditions.

Q215. Page 3-25, Section 3.3.9.2 - It is stated that the capability of the PCCS to vent a large accumulation of the specified noncondensible gas has been demonstrated by analysis. To what analysis does this refer?

R215. The statement referred to a simplified analysis that was performed in the early days of the SBWR program to show that the drywell pressure would rise to clear noncondensibles with conservative assumptions on the mixing and stratification of light noncondensibles. This analysis is no longer relevant with the availability of test data with light noncondensibles in PANTHERS, GIRAFFE/Helium and PANDA. The sentence related to the analysis will be removed from the next revision of the report.

Q216. Page 3-25, Section 3.3.9.2 - The following statements were made, "The ... PANDA P-Series tests provide definitive ... data on the issue of whether a light gas degrades the heat transfer of the PCCS more than a heavy gas under natural circulation conditions." The PANDA results from test P7 indicate (ALPHA-820-0, page 40) that the gas "accumulated in the PCCS and adversely affected PCCS performance ... additional investigations would be necessary to come up with final conclusions." Please document where the final conclusion has been made.

R216. [[

]]

Q217. Page 3-25, Section 3.3.9.2 - The wording of section 3.3.9.2 is not clear and should be improved.

R217. This section will be rewritten as follows:
[[

]]

Q218. Page 4-2 - The statement is made that, "...and possible sloshing between the reactor vessel downcomer and the suppression pool through the equalization line..." What could initiate or sustain such sloshing?

R218. The initial opening of the equalization line valve could result in manometric oscillations between the vessel downcomer and the suppression pool. Any oscillations would be damped out quickly (SBWR Scaling Report, Appendix C) and this scenario will not persist.

Q219. Page 4-3 (2nd paragraph) - (1) As stated, the passive autocatalytic recombiner (PAR) induced flow velocity in the DW is significantly less than the maximum PCCS inlet flow velocity. How does the PAR-induced flow velocity compare to the average PCCS inlet flow velocity during the long-term PCCS cooling phase (which does not include the GDCS injection phase)? (2) "Primary Containment Cooling System (PCCS)" should be replaced with Passive Containment Cooling System (PCCS).

R219. (1) This issue is deferred to the certification phase of the ESBWR program as it is outside the current review scope for TRACG application. (2) The typo will be fixed in the next revision of the report.

Q221. Pages 4-5 to 4-21 - Are there any high-ranked ESBWR phenomena that were not ranked "high" (7 or higher) in the PIRTs for SBWR?

R221. [[

]]

Q222. Page 4-12 - Please explain why Table 4.1-2a (Composite List of Highly Ranked Phenomena for LOCA/Containment) does not list vacuum breaker leakage as a high-ranked phenomenon. Note that based on PIRT parameter definition (p. S-42 of TAPD Supplement 1, "Discussion of PIRT Parameters"), vacuum breaker leakage is not part of "Vacuum breaker mass flow" or "DW/WW boundary leakage." Issue T10/11 (p. 3-14) also shows a high ranking of 9 for VB steam bypass/leakage.

R222. [[

]]

Q223. Page 4-21- Please explain why flashing in the chimney region is not listed as a high-ranked phenomenon in Table 4.1-5a (Composite List of Highly Ranked Phenomena for Stability).

R223. Flashing in the chimney due to static pressure differences is only important at low pressure, for example during startup conditions. Plant startup is covered under operational transients. Stability evaluations in Table 4.1-5a refer to operating pressures where flashing effects in the chimney are insignificant.

Q224. Page 5-2 (3rd paragraph) - There is a typographical error. "Omtario Hydro" should be replaced with "Ontario Hydro."

R224. This will be corrected in the next revision of the report.

Q226. Page 5-13, Section 5.2 - Were any tests performed directed at the question of avoiding backflow leakage in the GDCS drain line from the RPV to the wetwell?

R226. Backflow leakage in the GDCS drain line from the RPV to the wetwell does not have a direct path either during operation or during an accident situation. During operation, the closed squib valve provides the seal between the RPV and either the GDCS pool (via the injection line) or to the wetwell (via the equalizing line). In the event of an inadvertent squib valve actuation, the biased-open check valve will close to prevent backflow.

During an accident scenario when the squib valves have opened, the biased-open check valve prevents any significant backflow leakage from either the RPV to the GDCS pool or from the RPV to the wetwell through the equalizing lines. These check valves are not designed to be totally leak tight therefore some small leakage may result. Please refer to RAI #349 for a discussion of backflow leakage observed during the PANDA tests M9 and P2.

Q227. Page 6-2 - (1) "Table 6.1" should be replaced with "Table 6.1-1" (as shown on the next page and also on the 4th line on Page A-6). (2) On the 4th row (Geysering) and 5th row (Plant startup), "F4" (Geysering during startup) should be replaced with "F5" (see Table 2.3-3 on page 2-47).

R227. The above typos will be corrected in the next revision of the report.

Q228. Page A-5 (1st and 5th paragraphs) - Is "the vent tank flow control valve" or "the vent flow control valve" shown in Fig. A.3-2 (Page A-92) as PCV/2?

R228. Yes, the vent tank flow control valve is designated as PCV/2.

Q229. Page A-6, Section A.3.1.1.2, and Page A-16, Section A.3.1.2.2 - What is meant by "Concept Demonstration"? Is this the same as 'proof of principle?"

R229. Yes, the two terminologies are equivalent.

Q230. Page A-30, Section A.3.1.5.4 - It would seem that the key prerequisite to obtaining reasonable agreement between TRACG and GIRAFFE would entail reasonably accurate modeling of facility heat loss. How was this done?

R230. Heat losses in the GIRAFFE/Helium tests were established during facility shakedown tests. During the runs, the facility employed microheaters to balance heat losses to the ambient. Despite the microheaters, heat losses were significant. [[

]]

Q233. Page A-42, Section A.4.1 - It is not evident that TRACG is capable of calculating boron mixing. Have the mixing data been shown to be applicable to ESBWR?

R233. As explained in the report TRACG Qualification for SBWR (NEDC-32725P, Rev. 1) an application procedure has been developed to ensure that TRACG calculates the effects of boron mixing in the bypass conservatively; i.e delays the boron delivery to the core by a reasonable margin. Applicability of the tests was addressed in response to RAI 177 above.

Q235. Pages A-94 and A-95 - Are the steam mass flow rates and air mass flow rates shown in Fig. A.3-4 (“Comparison of PANTHERS/PCC Steam-Air Range to SBWR Conditions”) and Fig. A.3-5 (“TRACG PANTHERS/PCC Qualification Points”) for a single PCC unit in the SBWR?

R235. Yes, the points refer to a single PCC unit in the SBWR.

Q237. Page A-119 - Figure A.4-2 shows four SBWR conditions (at 0.1, 0.2, 0.35, and 0.5 MPa, respectively) in dimensionless subcooling numbers. Is there a similar figure to reflect the corresponding ESBWR conditions?

R237. The precise startup path for the ESBWR has not yet been fixed. TRACG analysis has been performed to look at possible startup trajectories. [[

]]

Q238. Page B-1 - (1) Please provide the reference for TRACG interaction studies discussed in Appendix B. (2) Please provide a list of all the safety grade systems that are not engineered safety features (e.g., isolation condenser system).

R238. 1) The TRACG interaction studies were reported in the SBWR TAPD, NEDC-32391P, Rev. C.
2) The isolation condenser is the only safety grade inventory control system that is not an engineered safety feature.

Q239. Page B-2, Section B.3 - Why does filling of the isolation condenser (IC) stop at the lower header elevation and not proceed further? Does the elevation of the attachment of the IC drain line to the downcomer uncover, or is it a matter of the gravity head of water that accumulates in the downflow side of the IC system?

R239. The IC condensate drain line nozzle is slightly above the water level when vessel depressurization occurs (ADS). Therefore the nozzle and drain line will be above the annulus water level. The pressure difference between the drain line nozzle and the upstream side of the depressurization valves is not high enough to cause an overall flow reversal in the IC heat exchanger. It is sufficient to reverse the drain flow and support a head of water in the IC up to the lower header.

Q240. Page B-5 - Does the "Min Chimney Level" in Table B.3-1 represent the two-phase mixture level (instead of the collapsed level)?

R240. Yes, Table B3.1 shows the two-phase mixture level.

Q241. Page B-6 - What is the physical reason for large differences in flow rates between the IC drain line and the supply line at t < 1.2 min and at t > 5.7 min during GDLB?

R241. [[

]]

Q242. Page S-3, Section S.1.3.1 - There is considerable discussion of counter-current flow limit (CCFL), however, it is not clear whether CCFL conditions are indeed to be expected or not. If so, where, when, and for how long?

R242. [[

]]

Q243. Page S-3 - It is stated that "Although the core is "covered," the local critical heat flux could be exceeded." Given the conditions of heat flux and void fractions during a LOCA in an ESBWR, how is this possible? In page S-5, it is further stated that, "Film boiling is not expected for the ESBWR LOCA...."

R243. [[

]]

Q244. Page S-8, Section S.1.2.1 - The *Summary* paragraph could perhaps more usefully be placed at the very beginning of Section S.1.3.1 as an introduction. The same is true for subsequent sections.

R244. Thus will be done in the next revision of the document.

Q245. Page S-8, Section S.1.3.2 - It is not evident how TRACG can be expected to represent the flows and locations over time of noncondensible gases. This observation applies to other containment phenomena, such as pool mixing and stratification, spillage of subcooled GDCS water from the RPV into the drywell, phase separation in the drywell, various plumes, etc. The ability to model non-condensible gases, presumably, is the reason for the statement (page 1-8, 1.2.1.3.4), "Key model parameters and input variables will be treated conservatively to produce a bounding calculation of the containment parameters of interest (pressure and temperature)."

R245. [[

]]

Q246. Page S-10, Section S.1.3.2 - It is stated that "Tests indicate that complete condensation of the steam entering the suppression pool occurs in the pool, even when the gas bubbles contain a significant amount of noncondensible [gases]." On page, S-11 it is, however, stated that "Early in the transient, large bubbles from the horizontal vents lead to level swell in the pool with potential break through the surface..." These two statements are contradictory.

R246. The statement on page S-10 does not apply to the initial air clearing transient. It is intended to apply for the subsequent phase where steam discharges into the suppression pool, accompanied by the remaining noncondensibles.

Q247. Page S-12, Section S.1.3.2 - It is stated that "The pool will be well mixed, and the temperature differences in the pool will not be significant." Why is this to be expected rather than the opposite?

R247. In the early part of the LOCA transient, the PCC pool is subcooled, with a strong natural circulation flow pattern. The heated water near the PCC tubes rises upwards and is replaced by cooler water from the sides of the pool. This stable natural circulation causes the pool to be well-mixed. After a few hours, the pool begins to boil because of the energy deposited in the pool. The vigorous boiling process maintains the pool in a well-mixed mode.

Q248. Page S-12, Section S.1.3.2 - It is also stated that "The region in the center of the tube bundle could trap voids." Explain the mechanism for trapping voids in the center of the tube bundle.

R248. [[

]]

Q249. Page S-13, Section S.1.3.2 - Drywell/Wetwell Boundary. It is stated that "Leakage from the drywell to the wetwell is an important issue for the long term transient." Besides the vacuum breakers, are there any other potential leakage paths that must be considered, such as wall penetrations at the GDCS drain lines, the PCCS and IC vent lines?

R249. [[

]]

Q250. Page S-16, Section S.1.3.3 - It is stated that "For the ESBWR, the flow transient is always gradual during startup and sudden reactivity insertion is not possible." Although the startup is gradual, it would seem that the transition in Richardson Number from stable stratified to mixed could possibly occur over a much shorter time interval.

R250. Thermal stratification in the lower plenum is mitigated by the operation of the Reactor Water Cleanup System. This system removes water from the bottom of the lower plenum and returns it through the cleanup system and heat exchangers to the downcomer. The ESBWR cleanup is unique in that it is combined with the shutdown cooling system. As such the cleanup function subsystem can increase flow during times of potential stratification. In addition, the lower plenum of the RPV has four separate drain lines connected to the two trains of the cleanup system, for greater water removal and mixing.

Q251. Question was addressed in July 9, 2003, meeting.

R251. No Response Required.

Q252. Page S1-iv of Supplement 1 - For LASL, it is suggested to add a statement in parentheses for clarification. [Los Alamos National Laboratory (LANL) is the current name for LASL].

R252. The change will be made in the next revision of the document.

The report states "The objective of this scaling report is to show that the test facilities properly 'scale' the important phenomena and processes identify in the ESBWR PIRT and/or provide assurance that the experimental observations from the test programs are sufficiently representative of ESBWR behavior for use in qualifying TRACG for ESBWR licensing calculations." Yet there is no such specific demonstration that these objectives were achieved in the report. Throughout the report statements about the "approximate" scale of each facility, and the varying scales of subsystems within the facilities abound. One specific example is the references to PANDA scale being 1:50 (page 1-1) and approximately 1:50 (page 5-6). There seems to be no metric for evaluating if the objective of the report was met. As section 8.1 states "No specific quantitative criterion exists to define what constitutes a well-scaled test." The next sentence in that paragraph is "A seemingly acceptable criterion that we adopt here is to maintain important phenomena within factor of around three of the prototype." What does seemingly acceptable mean, and how is this criterion determined? These arbitrary (or at least unjustified) evaluations of results are a repetitive theme throughout the report. Certain phenomena, distortions, physical dimensions or geometry are said to be negligible or unimportant without explanation or reference, as if they were axioms of the trade, obvious to anyone. One example of this is the choice of reference variables on pages 4-4 and 4-5. The report says that "A natural definition for Δ_{hr} arises..." There was no such demonstration. Despite the lack of metric, the report goes ahead and concludes (page 8-5) that "the phenomena important to the plant system behavior are well scaled in the test facilities thus providing useful data for TRACG qualification." The question of data sufficiency does not seem to be addressed directly.

The report refers to some of the non-dimensional coefficients as if they were phenomena and to others as ratios of system variables. In some cases, the ESBWR values are outside the bounds of the experimental space. This means that the experiments do not represent the particular phenomena associated with that non-dimensional coefficient and the data matrix is insufficient. This is the case for the stored energy. How are these phenomena accounted for in the analysis and in the qualification of TRACG?

There is a discussion in the report regarding characteristic times. Some of the times mentioned seem to be the same concept recycled (connecting lines appear associated with multiple time scales) and most of the definitions seem imposed instead of derived. In reality, however, for a complex dynamic system, independent subsystems or components will contribute to the system behavior with their inherent time constant. For example, an emptying tank has an associated time constant, function of its cross sectional area and the outlet resistance to flow. A tank that is filling up by an input flow is not an independent component because its dynamic response is determined by the magnitude of the incoming flow. The comparison of the characteristic times of independent components is the proper way to determine the relative time scales between processes or modes of a dynamic system. It is not clear that this rigorous approach was actually followed. It appears that the generic control volume that was introduced in chapter 3 was used repeatedly to model not only the different facilities, but also the different phases of the transient. This may explain why all the phases of the transient wound up described by a

single first order differential equation in time, as opposed to a system of equations. While this final result may still be valid in most cases, it is not clear if the other dynamic features of these systems were neglected. What is the reasoning to exclude flow paths and multiplicity of tanks in the final description given to each phase? Where is the analysis that shows that all facilities can indeed be described with a single first order equation?

Even though it was mentioned as an objective of the report, the issue of data sufficiency is not clearly addressed. Is the data from these facilities sufficient?

These issues discussed above are addressed specifically in the following questions.

Q253. Section 2.2, page 2-2 - It is stated that for a facility to be perfectly scaled the values of all the PI numbers for prototype and model should be "perfectly matched." What does "matched" mean? Is it the mathematical meaning of congruency or is it something else?

R253. Perfectly matched refers to "the mathematical meaning of congruency" i.e. the PI groups having the same numerical values when numerical reference values are substituted in. It should be pointed out that this is not a necessary condition for the test facilities in the ESBWR test program. Rather, the ESBWR tests provide data for conditions in which the important phenomena or processes have similar magnitudes to those in the ESBWR so that the TRACG code can be qualified against the data. The code is then used to predict the plant response. This is different than a prototype test, which is used to predict the system behavior by itself. To meet the stated requirements, of providing data for TRACG qualification, the important phenomena and processes as indicated by the PI group magnitudes should be of similar magnitude in the tests and ESBWR. In addition the dominant processes should be the same in the tests and ESBWR.

Q254. The first paragraph in section 2.4 begins the discourse on response times and suggests many options. Each independent dynamic element of the system, each mode, has only one characteristic time associated with its dynamic response. What is the technical basis to suggest alternatives and in what instances were these alternatives proven to work better?

R254. Each element of a system can have several characteristic times. Which one is appropriate is dependent on the process of interest. For example a pipe has characteristic times associated with inertia and a transit time. Which characteristic time is of interest is dependent on what aspect of the system element is being studied and the dynamic behavior of the system as a whole. If the start up of flow due to a sudden change in the boundary conditions is of interest such as the initial clearing of the main vents at the beginning of blowdown, then the inertia time constant is of interest. During the long-term portion of an accident in the ESBWR the pressure boundary conditions evolve so slowly that the conditions in the pipe are quasi-steady and dependent on the pressures in the volumes that it connects. Pipe inertia plays no part in the pipe behavior for these conditions.

The section on time constants was intended to provide background for later discussions on specific time constants used. GE understands the potential for confusion between the terms "time constant" and "characteristic time" in the discussion of pipe transit times, and future revisions of the scaling report will use the appropriate terminology.

Specific selections of time constants for use in the scaling application sections are spelled out in the report. The appropriate reference time selected for each temporal phase is described in Section 7.3.2. The numerical values of the reference times are reported in the Tables in appendix A.

Q255. The system representation provided in Fig. 3-1 depicts a single generic volume with a water liquid phase and a multi-component vapor phase. In principle, this is a generic representation of any system. Specifically, how is this treated for the ESBWR design? How does it encompass the various portions of the transient where different components play dominant roles in affecting the overall system behavior?

R255. Figure 3-1 is a sketch of a generic volume because Section 3 develops the general, or generic, equations for mass, energy and pressure for a volume with gas and liquid. The specific applications are demonstrated in Section 7 for the ESBWR. The specific applications are applied to the test facilities in Section 8. For example the specific form of the equation for liquid mass in the RPV is shown in Figure 7-1. The processes of interest are shown in the sketch of the RPV in that figure. The PI groups shown in the boxes of the figure indicate the individual processes considered. The magnitudes of the processes are shown by the bar chart in the bottom right portion of the Figure. This specialization is repeated for other temporal phases, regions and parameters (e.g. pressure) in subsequent figures. Rather than limiting the equation to processes that are expected to be dominant for the phase, all of the processes are considered and the magnitudes of PI groups indicate if the process is important or not. This same procedure is applied to the test facilities in the figures of Section 8.

Q256. Section 3.1 - The generic equations derived for this system representation do not include explicitly important terms that are key in assessing the relevance of the various scaling groups. How can one relate the generic scaling groups derived in this report with the ESBWR key phenomena and components?

R256. The generic equations developed in Section 3 are made specific in Section 7. The specific equation representations in Figures 7-1 through 7-7 show the equations used for each system volume. The sketch in the left portion of each Figure indicates the processes considered and the variable name for each process. See response for RAI 255 also.

Q263. The system clearly presents a variety of time scales. According to the definition of the volume residence time it follows that, since $V_r \sim A_r L_r \sim R$; $W_r \sim R$ and $\rho_r \sim 1$, the only possible time scale is such that $t_r \sim 1$ or that there is isochronicity. The report concludes that this is the case. However, it appears that the report, in section 4.6, considers this choice as arbitrary and that there could be other possibilities. Please explain how this apparent degree of freedom is introduced.

R263. For the scaling method used there should be isochronicity, $t_R \sim 1$. The confusion seems to arise from the use of upper and lower case r in the subscripts. Lower case r is used to indicate reference values and gives no indication of the ratio of the ESBWR value to the test value. Upper case R is used to indicate the ratio of an ESBWR value to a test facility value.

Section 4.6 discusses several time constants for different processes. The lower case r in these equations indicates that they are reference values. These equations do not indicate any scaling ratios. Application of any of the time constant equations in Section 4.6 to both the ESBWR and test would result in a time constant ratio of $t_R \sim 1$.

Q265. Section 4.2, page 4-4 - It is stated that "A natural definition for Δ_{hr} arises ¼" What is the basis for that statement?

R265. Section 4.2 refers to phase changes at interfaces. The typical energy carried away from these interfaces is given by the difference between the liquid and vapor enthalpies. Therefore the recommended value for enthalpy differences is $\Delta h_{fg,r}$. Since prototypical fluids are used in the tests any other selection for Δh_r would result in the same scaling ratio of $(\Delta h_r)_R \sim 1$. To avoid any confusion in the future subsequent revisions to the report will be revised to use the term "rational definition" rather than "natural definition".

It should be noted that this section relates to general equations for system design. In later sections where the equations are applied to specific system elements, the local enthalpy differences are used as reference enthalpy differences in order to assure that the normalized enthalpy differences have magnitudes very close to 1. As a result the confusion described above is eliminated in the specific applications.

Q267. The sentence before equation 4.3-7 in page 4-6 refers to a demonstration in section 4.2 ("it was shown ¼"). There was no such demonstration in section 4.2.

R267. See answer to question 265. Future revisions of the report will be changed to say that "$\Delta h_{fg,r}$ is the rational choice for Δh_r" rather than "it was shown…".

Q268. The second paragraph of section 4.4 states that reduced velocities in the models is not important as long as transit times between volumes are small compared to volume fill times. Transit times, or delays, are important when a discontinuity or a signal is carried from one end of the transmission line to the other. In the case of this thermal-hydraulic system, in which the lines are either full of water or steam, it is not clear why a line delay plays any role in the dynamic response of the system. What is the importance of the transit time? What is the basis for these comparative statements between transit times and filling up times?

R268. Section 4 provides a discussion of general scaling laws for use in test design. Therefore it is not restricted to "this hydraulic system" as stated in the question. When the specific situation present in the ESBWR is considered, the transit times are not important as suggested by the RAI.

Q269. Page 4-10 has a similar statement that upgrades transit time to the category of time constant and says that it must be compared to other time constants of the system. If transit time depends on the flow, which in turn depends on pressure and hydraulic heads, it is not a constant. Why is this transit time relevant?

R269. As pointed out in RAI 268, in some cases transit times can lead to delays which can in turn effect the timing of the pressure response of the receiving volume. In cases where the pressure of the receiving volume is important to the flow rate, and therefore transit time, in the pipe, there can be important interactions between the pipe and the receiving volume. For the specific application to the ESBWR the time constant of the large volumes are much longer than the pipe transit times and there are no interactions. As discussed in the response to RAI 268, the text in this section provides a discussion of general scaling laws. Therefore it is left broad enough to cover instances where the transit time can be important.

Q270. At the bottom of page 4-10, volume fill time is equated with residence time. Residence time is actually closer to a transit time than to a filling time. This statement needs correction or clarification.

R270. The use of volume fill time and residence time in this report is consistent with that described in Section 3.4.8 of "An Integrated Structure and Scaling Methodology for Severe Accident Technical Issue Resolution", NUREG/CR-5809, upon which the scaling method is based. However, the wording will be revised in the next revision of the report to minimize any confusion.

Q273. The stored heat in the massive containment structures is not represented in any of the facilities. This may yield conservative peak-pressure evolutions in the short-term. It is not clear whether that stored heat has an effect in the long-term portion of the transient and whether the stored heat affects that long-term noncondensible gas behavior. Provide additional discussion of the effect of stored heat beyond the paragraph 5.5.1.4.

R273. The containment structures are indeed massive but have very long thermal time constants so they absorb or reject energy slowly. The steel structures in the containment and the portion of the wall surface can absorb energy more rapidly, but this is similar to the steel structures of the test facilities. As discussed in Section 7.5.2.1and shown in Figure 7-6, the contribution of structures to the drywell pressure evolution is negligible. The contribution of structure stored energy to the wetwell pressure is larger but still small compared to the large pressure change which results from noncondensible gas accumulation in the WW, as discussed in Section 7.5.2.2 and shown in Figure 7-7.

The comparison of stored energy effects for the ESBWR and tests is shown in Figures 8-6 and 8-7 for the drywell and wetwell respectively. For the PANDA tests the heat entering the structures is scaled fairly well. The heat losses from the vessels in the PANDA facility were similar to the expected rate at which heat would be conducted into the walls of the ESBWR containment. The heat flow into the walls was not scaled as well in the GIRAFFE facility. In the GIRAFFE facility, the walls were fitted with microheaters in order to eliminate any heat losses. Therefore the heat loss in the GIRAFFE wetwell was approximately zero. This is a conservative result since heat loss in the wetwell would tend to reduce the steam partial pressure in the wetwell. The heat loss in the GIREFFE lower drywell were not compensated for and were fairly large as indicated by the structure heat loss bars in Figure 8-6. As shown heat loss to structures is a small contributor to overall pressure evolution in the drywell. The fact that these heat losses were concentrated in the lower drywell did cause a non-prototypical flow of noncondensibles to the lower drywell. This has been discussed elsewhere (see SBWR Testing Summary Report (NEDC-32606P), Section 4.4.4.3, for example).

Q274. The third paragraph on page 5-10 justifies the steady state test conditions for the PANTHERS PCC with a narrative analysis of time scales of the relevant components. What are the governing equations of these components and the exact values of the corresponding PIs that allow the narrative to be valid? What are the results of the same comparison for the other facilities and the prototype? What is the impact of these differences in their relative standing when it comes to validating the PIRT?

R274. [[

(274-1)

(274-2)

(274-3)

(274-4)

(274-5)

]]

Q278. The paragraph on the top of page 5-4 says that the initial RPV water level was increased to compensate for GIST's inability to represent the creation and sustenance of voids in the lower plenum due to stored heat. How does more liquid help represent voids? This paragraph seems to contradict the statement a few lines before about representative thermal-hydraulic conditions in the RPV. Please reconcile these statements reconcile.

R278. The following paragraph from the SBWR scaling report (Page 4-54) provides a better description of what was achieved by increasing the initial water level in the GIST tests,

> "The heat release from the RPV metal in SBWR could not be simulated in the GIST tests; the heat stored initially in the RPV wall and its rate of release could not be scaled properly. Thus, voids could not be maintained in the lower plenum and the water level in the core dropped; this was compensated for by increasing the initial RPV water level in the tests. This distortion can be considered in TRACG calculations which can simulate the situation in the tests and in the SBWR"

The additional water was not meant to "help represent void", but rather to better represent the two phase level which is a combination of liquid and voids. The "earlier statement about representative thermal-hydraulic conditions in the RPV" refers to the time for a void distribution to develop in the RPV at the beginning of the tests as discussed in the response to RAI 277.

Q280. There are some discrepancies between the PI groups listed on page 6-2 and those derived in Appendix A of NEDC-32606P, "SBWR Testing Summary Report," on page A-4. For example, the term □$M_{l,r}$ should be □$M_{l,o}$. Please clarify the nomenclature and definitions in order to resolve these discrepancies.

R280. The equations are consistent but the nomenclature is different for the two reports. Both the way that the PI groups were broken up and the subscript notation were different. In the SBWR, global scaling of the entire system was used and therefore there was a need for local and global reference values. These were indicated by the subscripts "r" and "o", respectively. Additionally, in the ESBWR scaling report, local reference values were distinguished as those where initial conditions were used and those where they were calculated. These were denoted by the subscripts "o", and "r", respectively. This distinction was not made in the older SBWR scaling report. The easiest way to see that the equations are the same is to substitute the reference variables in for the PI groups in both equations and use the subscript "r" in place of "o" in both equations. The resulting equations will be the same. All that is lost in doing this is the distinction of weather a reference variable was an initial condition or not.

Q283. In the proposed scaling, the condensation phenomena are eliminated by considering a flow of steam and noncondensible gases at the PCCS inlet as if this flow was not determined by the condensation rates within the PCCS. However, the condensation rate is the direct result of the presence of noncondensible gases. The proposed scaling approach does not address this effect, and may result in eliminating important scaling parameters thus misrepresenting the adequacy of the facilities. Explain how the proposed approach addresses this issue. In your explanation, provide a detailed technical justification for this simplification of your scaling approach.

R283. The condensation rate of the PCC is considered in the bottom-up scaling provided in Sections 3.6 and 4.4.1.3 of the SBWR Scaling Report, NEDC-32288P, Rev 1.

Essentially, the only difference between the ESBWR and earlier pressure suppression systems is the addition of a heat removal device (the PCC heat exchanger) in the flow path between the drywell and the suppression pool. In the earlier designs, all the decay heat energy was deposited in the suppression pool, and rejected from the suppression pool to the ultimate heat sink via the Pool Cooling Mode of the (active) Residual Heat Removal (RHR) System. In the ESBWR, the flow from the drywell to the suppression pool passes through the PCC heat exchanger, rejecting a large majority of the decay heat to the ultimate heat sink instead of the suppression pool.

It is important to understand that in any pressure suppression containment system, the long-term containment pressure is dominated by the wetwell air space response, not by the drywell[1]. (See the response to RAI 360.) In the latter stages of the LOCA, when the vent flow rate from the drywell to the suppression pool is reduced, the vent flow losses are negligible. During this time the drywell pressure is equal to the wetwell pressure plus the submergence head of the flow path between the drywell and the suppression pool. In the ESBWR there are 2 such flow paths – the main vent, and the PCCS system via the PCC heat exchanger and PCC vent. The PCC vent is at a higher elevation (lower submergence) than the main vent, making this the preferred flow path.

Consider a case where the PCC heat exchanger is replaced with a simple pipe from the drywell to the suppression pool, having the same submergence head. (Although flow losses are small during the PCC heat rejection period, even design this "pipe" such that the overall loss coefficient is the same as the PCC.) In this case the PCC "pipe" flow would be identical to that of the PCC system. The driving pressure difference is the same. The conclusion that is drawn from this analogy is that the PCC inlet flow rate is not a function of the condensation rate within the PCC.

---

1 Earlier BWR pressure suppression containment designs also experienced short-term drywell pressure peaks associated with vent clearing. For BWR/6 plants (Mark III containments) the short-term peak set the drywell design pressure. The long-term response is limiting in the ESBWR

When the PCC heat exchanger – for whatever reason – is incapable of condensing sufficient steam to reject the reactor decay heat, then the pressure at the vent will rise and clear suppression pool water from the vent. The excess energy will be vented to the suppression pool, however the drywell pressure will not exceed the wetwell pressure plus this submergence head. Some of the decay heat energy will be rejected to the environment via the PCC, and the remaining decay heat energy will be deposited in the suppression pool – raising the pool temperature. Thus, it may be seen that the PCC condensation rate is important in limiting the deposition of energy in the suppression pool, the suppression pool temperature, and therefore the wetwell pressure. An additional scaling equation has been added in the response to RAI 259, Part 1 to address this condition.

All of the testing and analysis performed in support of the SBWR and the ESBWR has demonstrated that the PCCS is a self-regulating system. If the condensation capability exceeds the decay heat load, the pressure in the heat exchanger will drop, and the water level in the bottom header and tubes will rise until an equilibrium condition is reached. Note that in this case no flow path exists from the drywell to the suppression pool and all the decay heat is rejected via the PCCS. If the decay heat load exceeds the condensation capability, then the pressure in the heat exchanger will rise, lowering the water level in the vent until the vent clears and a flow path exists between the drywell and suppression pool. If the cause of the decay heat exceeding the condensation rate was build-up of non-condensable gas within the heat exchanger, then the flow will purge the non-condensables out of the heat exchanger (transferring them to the wetwell air space). The purged heat exchanger will then be capable of rejecting all of the decay heat.

Q284. Page 6-5 - There is a paragraph titled "RPV Reference Values" which states that the pressure difference between the beginning and end of a phase is the value chosen as reference. Are these pressure values fixed values or do they depend on the transient? How are they fixed if they are fixed? If they are not fixed, what is the rationale to use a variable value as a reference? The same question applies to the statements of the first paragraph on page 6-6.

R284. The method of determining the reference values is described in Section 7.3. The initial pressure is fixed at the value at the beginning of the test and is not dependent on the transient considered. The test initial pressures for the test covering the late blowdown period are at an intermediate point in the blowdown process. The values were selected based on a trade-off between starting at as high a pressure as possible and the pressure capability of the facilities. The starting pressures are high enough that any disturbances resulting from test initiation would be fully completed before reaching the lower pressures at which GDCS flow initiates. The pressure at the end of the phase is fixed by geometrical considerations which control the time at which the GDCS flow will start as described in Section 7.3.1.

Q285. The first paragraph of Section 7, page 7-1, discusses about "governing equations summarized in Section 6." Section 6 has the equations for the control volume introduced in Section 3. Section 7 further states that these equations are "applied to the ESBWR." Does this mean that it is a working assumption that the control volume equation of Section 3 applies directly to the entire system in every phase of the transient?

R285. The control volume equation of Section 3 applies to each of the control volumes in the ESBWR (RPV, drywell, wetwell) not the entire integral system. A global momentum method was applied to look at the various volumes and flow paths as an integral system as part of the SBWR scaling report (NEDC-32288P, Rev 1). There was no useful information gained from the exercise. Therefore it has not been repeated as part of this report as described in Section 6.2 of this report. The working assumption is that the control volume equations introduced in Section 3 do apply to each control volume in the system. The specific sources of heat and mass are supplied for each individual control volume as described in Section 7.

Q287. The last paragraph on page 7-2 appears to state that each model equation is normalized in each phase with a common reference time, and that this makes distortions resulting from timing differences transparent. It is not clear from the discussion what this means. Are any of the facilities operating at a different time scale that the prototype? What does it mean to use a common reference time? Is it a common definition that may change in numerical value from facility to facility, or is it a rigid choice given by one or more of the facilities? How important (quantitatively and in terms of PIs) are other competing processes during each phase?

R287. The common reference time is based on a common definition but can have different numerical values from facility to facility due to differences in the reference parameters. The use of common reference times is only relevant when more than one control volume equation is evaluated for the same time period as is the case for the late blowdown and GDCS transition phases in the RPV. During these phases both the pressure rate equation and liquid mass rate equations are evaluated as indicated in Table 7-1. It would be possible to select a blowdown time constant based on the pressure rate equation and a draindown time constant based on the liquid mass equation. Doing so, however, would decouple the scaling of the pressure and mass in the vessel. It is important to maintain the relationship between pressure and mass since the timing of GDCS injection is dependent on the vessel pressure.

Therefore a time constant based on the depressurization rate is used for both the pressure and mass equations, as described at the bottom of page 7-3. Although equation 7.3-3 is used for all of the facilities, the numerical values calculated for the time constants, are different due to differences in the facilities. These time constants are then applied to the mass rate equation also. This cross coupling highlights differences in the depressurization rate and mass loss rate for the different facilities. Also see the response to Question 289.

The relative importance of competing processes can readily be seen in the bar graphs in Figures 7-1 through 7-7. The height of the bar indicates the strength of the process.

Q288. Immediately after Eq. 7.3-2, the term H_{GDCS} is introduced. However, this term does not appear in the equation nor in any other portion of the text. Clarify the reference to the "the vertical height of the liquid filled GDCS line".

R288. The generic variable L_m in equation 7.3-2 should be replaced by the variable H_{GDCS}. The correction will be made in future revisions of the report.

Q289. In Eq. 7.3-3, the reference time is arbitrarily set although isochronicity was previously established. The right hand side of this equation is of fundamental relevance to the scaling analysis, describing the energy lost via the ADS is compared with the loss of liquid inventory. This should be the central element of the scaling question in the intermediate portion of the transient. Later, in the scaling results section, it appears that matching the depressurization transient overshadows the key issue: how much water is lost as the pressure drops. Matching the pressure traces is a relatively easy task. It is the inventory relationship to the depressurization that relates directly to the adequacy of a given facility in representing plant behavior. An example of the consequences of this topic will be given in the comments concerning Section 8. Provide a description of the criteria used to evaluate the facilities.

R289. See responses to questions 253 and 287. The relationship between depressurization rate and inventory loss is addressed by using the depressurization time constant for both the pressure rate equation and the liquid mass equation. The time constant for each facility is based on its depressurization rate. Since the duration of the phase is set by these time constants the reference mass loss during the phase represents the mass lost during a similar amount of depressurization and therefore links the pressurization rate and inventory loss rate. If a separate time constant based on the mass equation were used for the mass equation, then it would be possible to show that the pressure rate and inventory loss rate are each well scaled individually, but there would be no indication that the depressurization rates relative to the mass loss rate are similar.

Q291. In the final paragraph of Section 7.6, "Bottom-up Scaling," the issue of noncondensible gas mixing and segregation is dismissed. What is the rationale for using the PANDA facility if its data are not used to resolve this issue?

R291. The importance of stratification and mixing is in influencing the timing and rate for noncondensables reaching the PCC and the wetwell. As described in the report *TRACG Application for ESBWR* (NEDC-33083P) a bounding approach is used to address stratification and mixing when applying TRACG to ESBWR analysis. The PANDA tests provided information on noncondensable release over a wide range of timing and rates. This information is useful in ensuring that the most bounding combination of release rate and timing has been applied in the TRACG application. As expected the impact of various release timings and rates on the peak containment pressure is small. The intent of the PANDA tests is not to simulate the stratification and mixing that would be expected in the ESBWR since the relatively simple open geometry cannot possibly simulate the complicated geometry in the drywell of the ESBWR with all of the equipment and relatively confined spaces.

Q300. In Table 3.4-1 of NEDC-33083P, phenomena identification and ranking table (PIRT) phenomena DW1 and DW4 are identified as "Insensitive." How were these determinations made? PIRT phenomena DW2, DW3 and WW5 are also identified as "Insensitive," based on Reference 82, NEDE-32178P, Rev. 1, "Application of TRACG to Model the SBWR Licensing Safety Analysis," January 1998. Provide a description and the results of the evaluation performed to make these determinations. If DW1 and DW4 were also addressed in NEDE-32178P, include these in the response. (NEDE-32178P is not identified as a report in support of the ESBWR pre-application review.)

R300. [[

]]

Q302. Question was addressed in July 9, 2003, meeting.

R302. No Response Required.

Q303. Question was addressed in July 9, 2003, meeting.

R303. No Response Required.

Q318. The qualification report for application of TRACG to the ESBWR design indicates that the code version used for the assessment calculations was TRACG02A. The intended code of record is to be version TRACG04. Please confirm and verify that no changes would occur in the calculations when performed with the later version of TRACG. If any changes would occur in the calculated results, submit the corrections to the qualification cases.

R318. [[

]]

Q320. The uncertainty analysis methodology for the application of TRACG to AOO events is described very well. Please provide a detailed description of the methodology by which uncertainties are determined for the application of TRACG to the LOCA.

R320. The Application Report sections on ECCS/LOCA and AOOs were compared with a view of providing supplementary information for the ECCS/LOCA section.
[[

]]

Conformance with 10CFR50.46 criteria requires that:

Peak Cladding Temperature (PCT)	<	1477 K
Peak Local Oxidation (δ)	<	17%
Core-wide oxidation (o)	<	5%

If the absence of core heatup is established with a high level of confidence, these criteria are automatically satisfied.

Q322. NEDC-33083P, Section 2.2.1.2 defines the Main Steam Line Break (MSLB) LOCA scenario. It assumes that the feedwater flow is not available during the transient. From the emergency core cooling system (ECCS) LOCA evaluation perspective, this assumption leads to conservative ECCS performance evaluation. For containment analysis, it is the common practice to assume that the feedwater flow is available during the LOCA and the injection continues until all the hot water from the feedwater system is consumed. Please provide justification and explain why the feedwater flow is assumed to be cut off during MSLB and why it is conservative to do so.

R322. For the MSLB containment response analysis, the SAR calculation will assume an appropriate feedwater flow (based on the final design of the feedwater system), consistent with past practice. The calculation performed in NEDC-33083P assumed a simplified feedwater flow coast down in the analysis. It is expected that the assumption of the feedwater flow coast down will have a very limited impact on the ESBWR MSLB response because the peak containment pressure for this break is determined primarily by the wetwell volume and GDCS pool partial drain down. Since any reasonable addition of feedwater flow will not impact the wetwell airspace and GDCS drain down volume, any impact on the containment pressure is expected to be minimal. The impact of any added energy with the feedwater system is also different (compared to standard BWR's) for the ESBWR as the design has a PCCS system, which would remove any additional energy without significantly heating up the suppression pool.

Q328. TRACG models the two-phase flow in the chimney using three large 3-D vessel radial rings instead of 1-D pipe components.

Q328.1. Does the 3-D vessel component result in the same flow regime as 1-D pipe components if 1-D components have been used to model the chimney?

R328.1. [[

]]

Q328.2. For the open space above chimney and below the separator inlets, what would be the flow regime there during normal operation? Is it possible that, during the normal full power operation, steam and saturated liquid would tend to separate in this open space and the volume averaging approach may not be valid?

R328.2. [[

]]

Q328.3. TRACG 1-D Pipe component has been validated against Ontario Hydro test data. Does this validation apply to 3-D Vessel component too? How? Does Ontario Hydro test data cover both ESBWR full power operation condition and start-up operation? During the start-up, when the channel outlet void fraction is small (in the bubbly flow regime), is it possible that the void tend to flow preferably in a small region in the chimney or the open space above to form a high void concentration region so that the averaging by TRACG would over-estimate the two-phase natural circulation driving head?

R328.3. [[

]]

Q332. On Page 2-36 of NEDC-33083P, it is stated that "There are three GDCS pools in the ESBWR containment, supplying four divisions of GDCS to the vessel." Based on the ESBWR design description, there is only one division of GDCS for each GDCS pool. Please clarify the total number of divisions from GDCS pools.

R332. The ESBWR Design Description, NEDC-33084P, Section 4.1.2.1, "GDCS Short-Term Subsystem Requirements", states:

> The required total RPV injection flow rates, as established by appropriate ECCS analyses, shall be supplied from three separate, non-divisional, GDCS pools via a four-division set of short-term injection piping trains, with one of these three GDCS pools being connected to the RPV via two independent short-term injection piping trains and each of the other two GDCS pools being respectively connected to the RPV via single dedicated remaining short-term injection trains.

There are three (3) pools supplying four (4) divisions of GDCS. Also refer to the schematic shown in Figure 332.1.

ESBWR Gravity-Driven Cooling System - Simplified Schematic Diagram

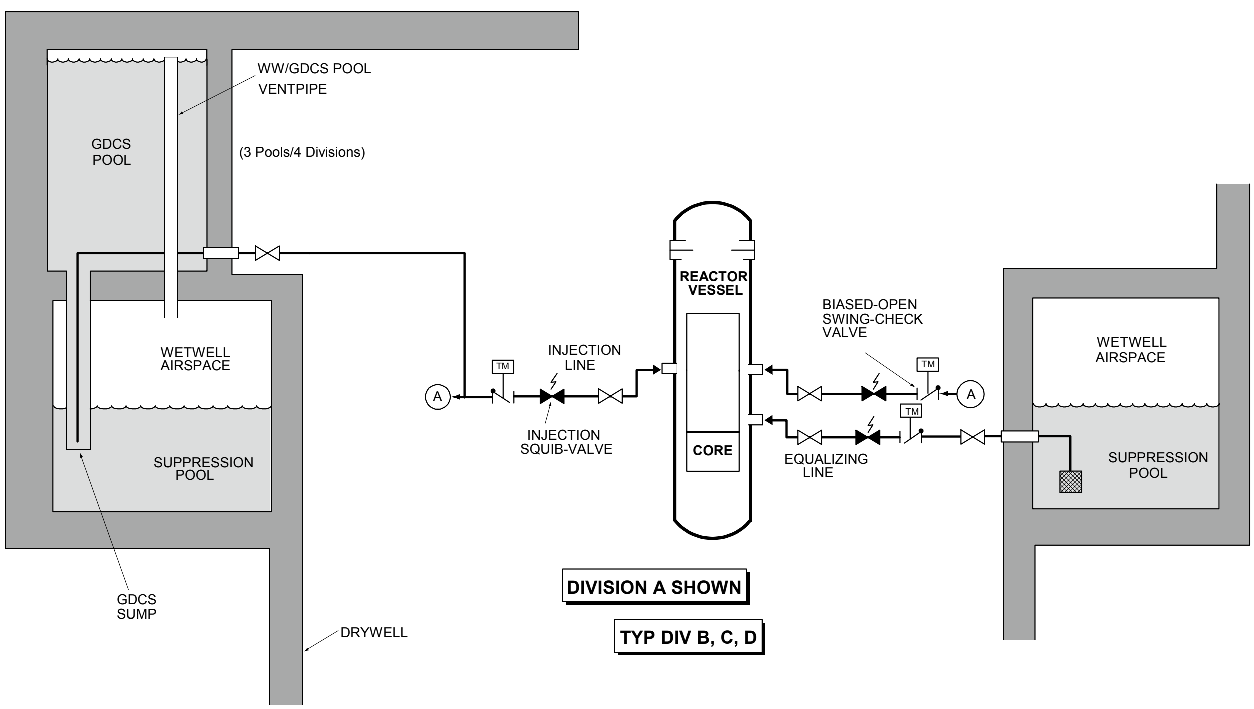

Figure 332.1

Q340. [[

]]

R340. [[

]]

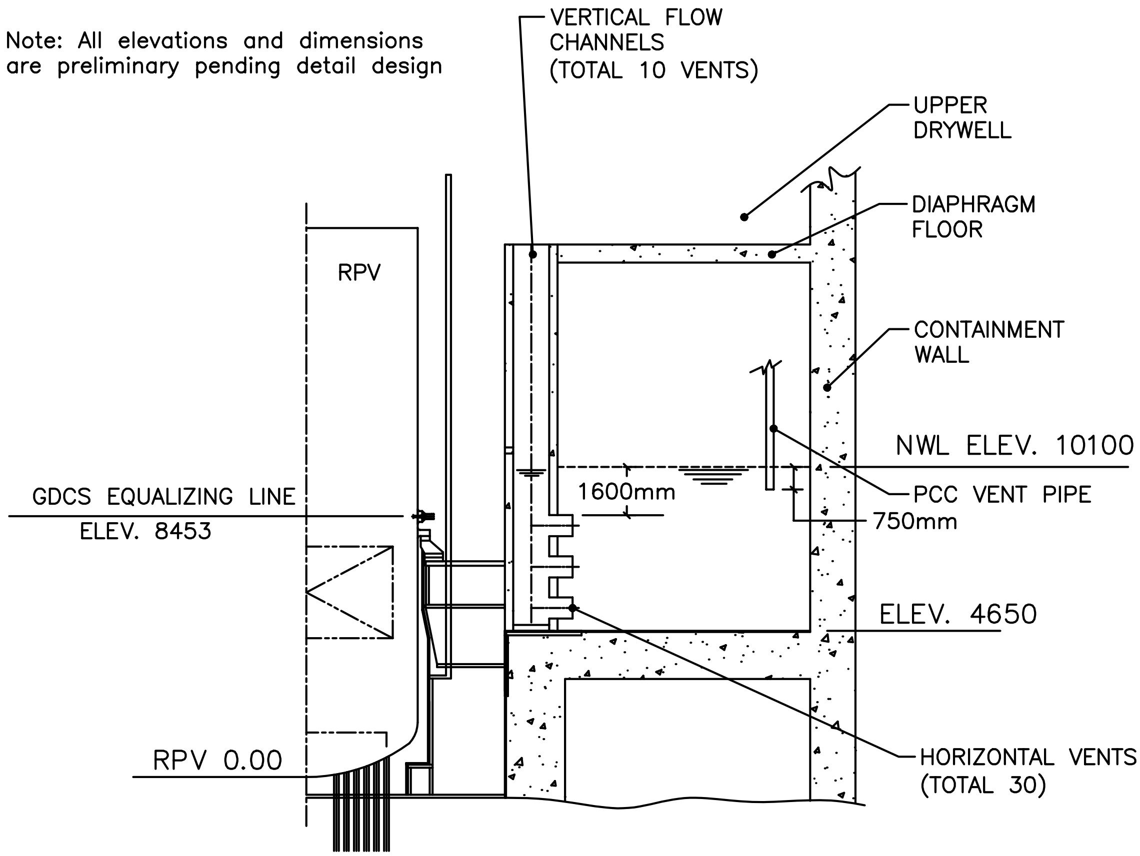

Figure 340.1 PCC Vent Submergence

Q341. What is the technical basis for setting the vacuum breaker (VB) opening pressure at 0.5 psi (i.e., the valve opens when the WW pressure exceeds the DW pressure by this amount)? We understand that the DW and WW can stand a maximum pressure differential of 3 psid. Has GE performed any TRACG sensitivity calculations or integral systems tests to determine the sensitivity of the peak containment pressure in a loss of coolant accident (LOCA) with respect to the VB opening pressure?

R341. [[

]]

Q342. [[ ]] Has GE performed any TRACG analysis to determine how much safety margin that the PCCS has? In other words, what is the minimum PCCS heat removal capacity required to prevent the peak containment pressure from exceeding its design value for the main steam line break (MSLB)?

R342. No TRACG analysis has been performed to determine the minimum PCCS heat transfer capacity to prevent the containment from exceeding the design pressure. We currently show more than adequate margin below the containment design pressure with the current PCCS design.

Q343. [[

]]

R343. [[

]]

Q344. [[

]]

R344. [[

]]

Q348. Page 2-4, last paragraph.

Q348.1. What is the technical basis to selecting a leakage path between the DW and WW of 1 cm^2 ($A/\sqrt{K}$) (where A is defined as the leakage area and K is defined as the loss coefficient) of 1 cm^2 for design basis accident evaluations.

R348.1. [[

]]

Q348.2. Since this leakage path is set at 1 cm^2 in the TRACG LOCA analyses, does it imply that K = 1?

R348.2. [[

]]

Q361. Pages 2-9 (last paragraph) and 2-25 (Fig. 2.1-2).

Q361.1. When the PCC vent tank was closed, was the vent valve shown in Fig. 2.1-2 (on top of the vent tank on the right-hand-side) shut off? If so, the pressure in the vent tank would rise if the pure steam flow into the PCC was not completely condensed.

R361.1. For the pure steam test, the vent tank vent valve was closed. The pressure in the PCC corresponded to that required for complete condensation. Tests were conducted by establishing the initial flow conditions. Incomplete condensation would cause the system pressure to rise until complete condensation occurred. The inlet pressure was allowed to stabilize while maintaining full condensation. After 10 minutes of steady performance (no change in inlet pressure), the data were taken. [[

]]

Q361.2. For the PANTHERS/PCC steady-state pure steam tests, did the vent tank pressure ever rise?

R361.2. During the steady-state pure steam tests after the test conditions were established (see response to (1) above), the vent tank pressure did not rise.

Q361.3. What action was taken if the vent tank pressure began to rise? (There seem to be two options: either reducing the pure steam flow rate to the PCC until the vent tank pressure stops rising and eventually reaches an equilibrium pressure, or maintaining the pure steam flow rate to the PCC until the vent tank pressure rises to a higher equilibrium pressure.)

R361.3. During each of the steady-state pure steam tests, the flow rate to the test apparatus was held constant and the vent tank pressure did not change. While setting up each test, the steam flow rate was first established and then the pressure in the system was allowed to change to that required to have complete condensation.

Q362. Page 2-10, 1st paragraph. Explain how the vent tank pressure was controlled in the steam-air steady-state tests.

R362. For the air-steam mixture tests, both the vent and drain lines were open. The vent tank flow control valve controlled the vent tank pressure. However, the test condition was specified by the inlet pressure. The downstream vent tank pressure along with the condenser performance controlled the inlet pressure. After setting up the test and 10 minutes of steady-state operation (constant inlet pressure), the data were taken. There was no adjustment of the vent tank flow control valve during data collection. [[

]]

Q364. Page 2-13, 2nd paragraph. Please provide a drawing of a spectacle flange.

R364. A spectacle flange, sometimes called a spectacle blind or figure 8 flange, is used in piping systems to allow normal flow in one configuration and to blank off or stop flow or pressure when the spectacle (blank) is reversed. A spectacle could be used where a local leak rate test is required and a component must be isolated in order to leak test. Please see the following figures representing the spectacle or blind piece and the flange unit.

Figure 364.1 Spectacle or Blind or Figure 8

The following sketch will also represent the flange plus blind configuration.

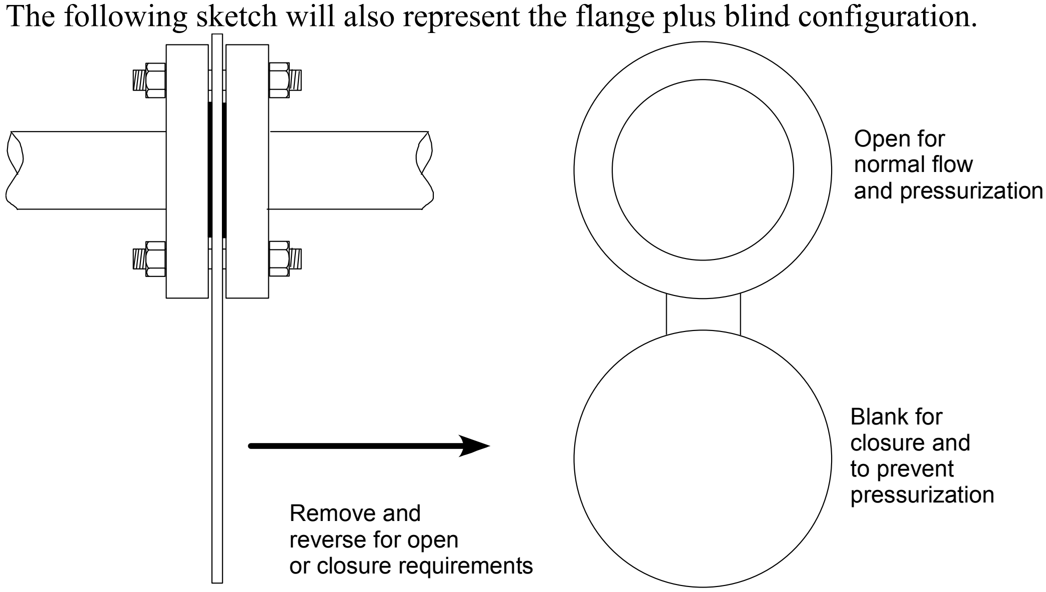

Figure 364.2 Simplified Sketch of Spectacle Flange

Q365. Page 2-14, last paragraph. Please explain the statement that "the pressure corresponds to that required to condense all of the given steam at zero air fraction."

R365. The pure-steam PCC tests determined the required pressure to result in complete condensation for different steam flow rates. Tests were setup by establishing the initial flow conditions and then allowing the pressure to fluctuate until a steady value was reached.

[[

]]

Q366. Page 2-24, Fig. 2.1-1.

Q366.1. What is the large vertical pipe connected to the lower header of the PANTHERS PCC shown in the left hand sketch of Fig. 2.1-1?

R366.1. The large vertical pipe is somewhat out of proportion for this sketch. This is the guard pipe that surrounds the condensate return and vent line, which are exiting the bottom horizontal header of the PCC heat exchanger. The guard pipe penetrates the concrete top slab of the containment and protects both the concrete and the pipes. This sketch is somewhat misleading and a better representation can be found in Figure 3.2 of "Thermal-Hydraulic Data Report of Panthers-PCC Tests, S. Botti, R. Silverii (SIET 00393RP95).

Q366.2. Why is this pipe not shown on the right hand sketch of Fig. 2.1-1?

R366.2. The guard pipe was left out in the right hand sketch. Again please refer to Figure 3.2 of "Thermal-Hydraulic Data Report of Panthers-PCC Tests, S. Botti, R. Silverii (SIET 00393RP95).

Q367. Page 2-27, Fig. 2.1-4.

Q367.1. As shown in Fig. 2.1-4, the pressure drop between the PCC top header and the bottom header is negligible. Are there any data to support this statement? Is this statement inapplicable to the steady-state and transient PANTHERS/PCC tests?

R367.1. Yes, we have data from the PANTHERS/PCC prototype heat exchanger test that supports the very low pressure drop. Delta pressure gauges DPT016 and DPT026, measured the pressure differential between the steam header and the condensate header for both heat exchanger shells.

The statement is applicable to the steady-state and transient PANTHERS/PCC tests.

Q367.2. [[

]]

R367.2. The vent line from the PCC heat exchanger was not submerged for the PANTHERS/PCC test. Also the top vent submergence is not applicable for the PANTHERS/PCC test since this is a component test only and not an integral systems test such as PANDA.

The Figure 2.1-4 referenced in the question is an expansion of Figure 2.1-3, which shows the PCC operating modes and ranges. Figure 2.1-4 shows how the PANTHERS/PCC tests covered the ranges and modes of the PCC operation. On Figure 2.1-4, vent, submergence, top vent submergence and vacuum breaker setpoint values are representative values and aren't applicable to the PANTHERS/PCC tests.

Please refer to RAI Number 335 response for discussion of vent submergence and its impact upon the containment pressure and temperature for the integrated tests. In summary, the range of vent submergences in the three integrated test programs had very little effect on the containment pressure and temperature and is judged not to be significant.

Q367.3. The VB setpoint of 2.1 kPa (0.30 psi) seems to be too low. Should the ESBWR/SBWR VB setpoint equal 3.45 kPa (0.50 psi)?

R367.3. [[

]]

Q368. Page 2-30, Fig. 2.1-7. What is the PANTHERS/PCC heat rejection rate with inlet steam flow at 5 kg/s and zero air mass fraction?

R368.

]]

Q369. Page 2-46, Fig. 2.2-1. The left hand sketch of Fig. 2.2-1 shows a large vertical pipe which is bigger in diameter than the vertical pipe housing of the isolation condenser (IC) vertical inlet line as shown in the middle sketch. Please explain this discrepancy.

R369. The large vertical pipe shown in the left hand sketch is a bit out of proportion. It is in fact the vertical steam supply line and its surrounding guard pipe. The steam supply pipe branches into two horizontal supply lines at the top of the pool. The vertical steam supply line is located inside of the larger guard pipe. A better representation can be found in Figure 3.2 of "Panthers-IC Test Report, R. Silverii (SIET 00458RP95).

Q370. Page 2-54, 1st paragraph. To avoid confusion, it seems appropriate to replace the statement, "The PCC/IC pools were isolated for this and all subsequent tests, " with the following statement: "The PCC/ICs pools were not interconnected for this and all subsequent tests."

R370. The statement will be changed to read, "The PCC/ICs pools were not interconnected for this and all subsequent tests."

Q377. Page 2-77, Fig. 2.3-7. Was the tube wall temperature shown in Fig. 2.3-7 measured at the inside surface of the condenser tube?

R377. No, the tube wall temperature shown in Figure 2.3-7 was derived from a thermocouple, soldered at the bottom of a groove that is about in the middle of the tube wall thickness.

Q386. Pages 2-112 (last paragraph) and 2-118 (Table 2.6-1). As stated, a single GDCS pool in GIRAFFE is equivalent to all three GDCS pools in the SBWR, and only one of the three GDCS pool would have pool-to-RPV flow under a GDLB with a single failure of a GDCS injection valve (Table 2.6-1) connected to one of the two remaining intact pools. We have two questions regarding this statement.

Q386.1. Is it correct to say that for a GDLB in the SBWR concurrent with an injection line valve failure on another GDCS pool, two out of the three GDCS pools can still provide water injection to the RPV? Each of the three GDCS pools in the SBWR has two injection lines connected to the RPV; if an injection line fails to open because of a valve failure, the other line can still provide water from this pool to the RPV.

R386.1. Your statement is correct for the SBWR configuration. Two out of three pools will drain to the vessel, with the draining of one of the pools being somewhat slower due to the failed injection valve on that pool. Also to be perfectly accurate, if one GDCS line breaks on pool A (for example), and one (out-of-two) injection valves fail on pool B, some of the water from pool A will still drain to the vessel, while the majority of water from pool A will drain to the lower drywell.

Q386.2. Similarly for a GDLB in the ESBWR with an injection line valve failure, how many GDCS pools (a total of four in the ESBWR) are available to provide water injection to the RPV?

R386.2. For the ESBWR design, one division of GDCS was added so that there are now four divisions. There are still only three water pools. Two divisions share one pool. With a GDCS line break the majority of one pool will drain to the lower drywell

Q407. What is the uncertainty of the modified Zuber critical heat flux correlation? Please calculate the hot channel departure from nuclear boiling ratio (DNBR) through out the entire high void flow condition and demonstrate that adequate margin exists. Please provide justification that the current DNBR calculation is conservative enough to ignore any sub-channel flow effects.

R407. [[

]]

RAIs related to GE Topical Report, GEFR-00850,
"Simplified Boiling Water Reactor (SBWR) Program
Gravity-Driven Cooling System (GDCS) Integrated System Test – Final Report"

Q409. General Electric (GE) topical report, GEFR-00850**,** is dated October 1989. The TRACG code has undergone changes since that time. Please confirm that the TRACG results presented in this report will be replaced by relevant analyses performed with the code version to be used for ESBWR design analysis.

R409. The GIST vs TRACG comparisons shown in GEFR-00850 have been replaced in Section 5.1 of the report TRACG Qualification for SBWR, NEDC-32725P, Rev.1. The latter calculations were performed with TRACG02. Calculations with TRACG04 are not expected to result in significant differences. This will be confirmed by rerunning sample cases with TRACG04 prior to use of the code for design.

Q410. GE topical report NEDC-33079P, "ESBWR Test and Analysis Program Description (TAPD)," list phenomenon [[ ]] – as a medium ranked phenomenon that is covered by the GIST test data for validation of TRACG. The percolation phenomenon that occurred during the main steam line break test [[ ]] was apparently not predicted by the version of TRACG used at that time. Section 4.3.3.1 of the TAPD report offers this as an explanation of the differences in depressurization predictions. While entrainment would not be expected to be as important for the ESBWR design, compared to the GIST facility, due to the presence of steam separators and dryers in the ESBWR, it is nevertheless listed as a medium ranked phenomenon in the phenomenon identification and ranking table (PIRT). As such, one would expect TRACG to be assessed to predict entrainment. Does the version of TRACG to be used for ESBWR design analysis correctly predict the [[ ]]? If the GIST data are used to assess TRACG for droplet entrainment, do the important dimensionless groups (e.g. Weber Number, Reynolds Number) cover the range of the ESBWR? If the GIST data are not used, what data are used for TRACG assessment for this medium ranked phenomenon?

R410. There are several statements made by the reviewer that need to be sorted out. The primary focus of the question appears to be on droplet entrainment. The comment on the percolation phenomenon is irrelevant to the question and has been addressed in another RAI (343). There is no Section 4.3.3.1 in the TAPD. Presumably the reviewer is referring to GEFR-00850.

[[

]]

Q411. The TAPD report lists a number of phenomena (E8 – break flow, E1 – break uncovery, E3 – cold water injection below the 2-phase level, E7 – cold water injection above the 2-phase level) related to the GDCS line break flow where assessment data are provided by the GIST tests. [[

]] Please explain how this limitation of the GIST data is addressed in the TRACG assessment.

R411. [[

]]

Q412. Section A-3.1.4.1 of the TAPD report states that GIST facility is vertically scaled [[ ]]with SBWR, but this appears not to be the case for ESBWR. The electrically heated rods that model the fuel in GIST are [[ ]], whereas the ESBWR fuel rods are [[ ]]. How is this difference in vertical dimension handled in using the GIST data to assess models for ESBWR applications?

R412. [[

]]

Q413. Void distribution in the core region is correctly not included as phenomena that the GIST data cover. The presence of non-prototypical cold surfaces next to every heater rod will tend to increase liquid flow through the rod bundle to the upper plenum. Phenomenon F1, void distribution/2-phase level in the chimney and upper plenum, will be affected by the larger amount of liquid entering this region. How is this addressed when these data are used for TRACG assessment of upper plenum/chimney void distribution?

R413. [[

]]