Request for Additional Information (RAI)
ESBWR TAPD, Scaling and Testing
ESBWR Pre-Application Review
General Electric Company

NEDC-33079P "ESBWR Test and Analysis Program Description"

177. Comparison of non-dimensional parameters (similar to one presented for SBWR and CRIEPI in Table A.4-1 of NEDC-33079P), or dimension-less groups (PI-Groups) should be derived based on scaling analysis, and their numerical values should be compared for ESBWR with the test facilities in order to provide assurance that the test facility represents the ESBWR design. As indicated in Table 6.1 of NEDC-33079P, GE qualified TRACG code for its application to Anticipated Transient without scram (ATWS) and Stability events in ESBWR against the following facilities: 1/6 Scale Boron Mixing Test, CRIEPI and Dodewaard. GE, however, did not present comparisons of representative parameters for ESBWR design and the above facilities in the submittals. The staff, therefore, requests GE to submit scaling analyses for the above mentioned test facilities, and provide comparisons of dimension-less parameters as discussed above, between ESBWR and the test facilities in order for GE to qualify TRACG code for its application to ATWS and Stability events in ESBWR against the test facilities.

178. 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].

179. Page A-122 - In Table A.5-3, the TRACG analyses for PANDA P-Series tests focus entirely on containment phenomena*, and this is 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, it is desirable to revise Table A.5-3 and "TRACG Qualification for ESBWR" to include the vessel parameters such as 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.)

180. 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 – PANDA M3, PANDA P2, and GIRAFFE/Helium H1. If not, please provide the comparison.

181. 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)?

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

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

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

185. In section 2.2.1, the statement is made that "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?

186. Page 2-3, Section 2.2.1.1 - The statement is made that, "This setpoint *(referring to Level 3)* is assumed to scram the reactor." Will the level scram setpoint be reached before the drywell pressure scram setpoint?

187. Page 2-5, Section 2.1.1.2 - For the last paragraph an elevation diagram would be helpful to the discussion.

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

189. 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?

190. Page 2-9 (last paragraph) - It is stated that water collected in the drywell can spill into the wetwell through the spillover holes in the pipes connected to the horizontal vents. Please provide a sketch to show the elevation and diameter of the spillover holes and

explain why their presence will not adversely affect horizontal vent clearing in a loss of coolant accident (LOCA) if this is not obvious from the sketch.

191. Page 2-12 (4th paragraph) - Under what conditions will the subcooled water be sprayed into the steam dome of the reactor vessel? Where is the source of the subcooled water?

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

193. 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?

194. 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)?

195. Page 2-16 - (1) What is the water level in the loop seal (during normal full-power operation) between a passive containment cooling (PCC) unit and its condensate drain tank? (2) Is there any water in the PCC condensate drain tank during normal full-power operation?

196. 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?

197. 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)?

198. 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 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?

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

200. 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/processes phenomenon identification and ranking table (PIRT)? Is this aspect considered to be covered by the Bottom-Up process?

201. Page 2-27 - The first paragraph states, "A smaller subset actually turned out to be important after the tests and sensitivity studies were analyzed." While the historical development aspect of the PIRT is of interest, it would be most helpful if the most current ranking were included here in some way. The presence of a unduly large number of highs and mediums tends to obscure the items of *greater importance* for those of *lesser importance*. Subsequent ESBWR reporting should preferably be based on the *latest* PIRT. This same comment extends to "3.3 Results," and so on.

202. Page 3-27 (No.2 - B11/4) - It seems that the suction lines of the Reactor Water Cleanup/Shutdown Cooling (SDC) System are connected either to the RPV downcomer annulus or to the RPV bottom head and the injection lines are connected to the RPV via the main feedwater lines. (1) Please provide a sketch to show "inlet and outlet nozzles located diametrically across the downcomer." (2) There is a typo in the fourth column. "CFD code calculations show sort circuiting will not occur" should be replaced with CFD code calculations show short circuiting will not occur.

203. 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) and FMCRD (Fine Motion Control Rod Drive) 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 and any FMCRD phenomena.

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

205. Page 3-1, Section 3.1 - Was the same expert group used in both bottom-up and top-down approaches? Were the two approaches done at the same time or apart in time?

206. Page 3-3, Table 3.2-1 - There is a typo – "hutdown" should be replaced with shutdown.

207. 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.]

208. 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 T/H

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 °F (instead of "less than 68 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 "Important T/H Phenomena" column)?

209. 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?

210. Page 3-19, Section 3.3.1.3 - Since core uncovery does not occur, why is this section covering, as it does, flow distribution in the chimney during reflood, relevant?

211. 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?

212. 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?

213. Page 3-23, Section 3.3.7.3 - The statement is made, "The vacuum breakers have been redesigned to preclude failure to close." What was the problem with the earlier design? Does this refer to insufficient valve stroke to meet minimum flow requirements (page A-41, A.3.2.4.3)?

214. Page 3-23, Section 3.3.7.3 - The statement is made that, "A separate isolation valve can be activated in the vacuum breaker." How will the operator decide to do this? How will the operator know which vacuum breaker is leaking?

215. 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?

216. 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.

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

218. 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?

219. 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) There is a typo. "Primary Containment Cooling System (PCCS)" should be replaced with Passive Containment Cooling System (PCCS).

220. Page 4-4, Section 4.1.2 - It is stated that "The high pressure makeup systems consist of the Isolation Condenser, which returns condensed steam to the vessel, and the Control Rod Drive System..." While the Isolation Condenser is a heat removal system, it seems inappropriate to call it a makeup system.

221. 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?

222. 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.

223. 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).

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

225. Page 5-13, Section 5.2 - Do the Moss Landing separator tests refer to the design to be used in ESBWR?

226. Page 5-13, Section 5.2 - Is there any qualification directed at the question of avoiding backflow leakage in the GDCS drain line from the RPV to the wetwell?

227. 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) There are two typos. 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).

228. 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?

229. 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?"

230. 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?

231. Page A-41 (1st paragraph) - Please provide a sketch to demonstrate the hard seat equivalent flow area.

232. Page A-42 (3rd paragraph) - Please provide a sketch to show the SLCS injection locations through the core shroud.

233. 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?

234. Page A-91, Figure A.3-1 - (1) Is the center vertical pipe (supplying steam to condenser tubes) insulated from the PCC pool water in the ESBWR design? Will there be any steam condensation inside the center vertical pipe during PCC operation? (2) Was the center vertical pipe insulated from the PCC pool water in the PANTHERS/ PCC tests?

235. 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?

236. Page A-96 - Figure A.3-6 shows an IC unit. (1) Is the center vertical pipe (supplying steam to condenser tubes) insulated from the IC pool water in the ESBWR design? Will there be any steam condensation inside the center vertical pipe during IC operation? (2) Was the center vertical pipe insulated from the IC pool water in the PANTHERS/IC tests?

237. 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?

238. 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).

239. 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?

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

241. 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?

<u>RAIs for NEDC-33079P, Supplement 1 "Discussion of PIRT Parameters"</u>

242. 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?

243. 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...."

244. 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.

245. 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 noncondensibles. This 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. This, 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)."

246. 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 noncondensibles." 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.

247. 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?

248. 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 tub bundle.

249. 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 the must be considered? For example, wall penetrations such at the GDCS drain lines, the PCCS and IC vent lines.

250. 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.

251. Pages S-30 and S-31 of Supplement 1 - Please provide drawings to show where CCFL may occur for PIRT Ref. Nos. A3, A6, A7, B4, and B5.

252. 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].

__RAIs for ESBWR Scaling Report, NEDC-33082P, Revision 0__

General Comments and Questions

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 of this in the report. In fact, throughout the report statements about the "approximate" scale of each facility, and even 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 scale 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 arrived at? 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 lengthy and cumbersome 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 rather 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, in fact, that the generic control volume that was introduced in chapter 3 was used again and again 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, we really do not know if the other dynamic features of these systems were arbitrarily neglected. What exactly 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? And how do we know that?

Specific Questions:

253. 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?

254. 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?

255. 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 particularized to the ESBWR plant? How does it encompass the various portions of the transient where different components play dominant roles in affecting the overall system behavior?

256. 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?

257. Section 3.1 - The reader is referred to Figure 3.2-1. There is no such figure in this report.

258. Equation 3.1-7 is incorrect. The dimensions of the second term of the right hand side do not match those of the other terms.

259. In the formulation of the generic governing equation, two elements require additional documentation.

260. The explicit representation of the condensation processes in the PCCS is the key element that links the system to its ultimate sink (the PCCS pool). How can the pressure be determined in the intermediate and long-term portion of the transient without the inclusion of this element?

261. The derivation of the vapor generation equation in Appendix B is referenced to the book of Lahey & Moody. In consulting the reference, there is no trace of such equation. Several assumption are needed to obtain the result cited in Appendix B. Please provide a detailed basis for the derivation of this crucial result?

262. The RPV liquid mass equation is derived in Appendix A. The derivation relies on the vapor generation formulation. It is surprising that no distinction is made between the short-term depressurization where the pressure in the RPV is independent of the containment conditions and the long-term transient where the containment pressure

affects the vapor evolution in the vessel. Please provide the rationale for deriving equations in a generic form without considering these significant differences in the various portions of the transient.

263. 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 indeed 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.

264. The scaling of vertical piping follows the traditional scaling approach. Nonetheless, particular care should be taken in locating the concentrated losses because the liquid level may or may not be present at these specific elevations of the piping during portion of the transient. Could you elaborate on the representation of the distributed losses with concentrated losses in view of this possibility.

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

266. The second paragraph on page 4-5 states that the flow mass flux due to phase change at the surface of a pool "may depend of the fluid conditions on both sides of the interface." Under what circumstances is the mass flux independent of the fluid conditions?

267. The sentence before equation 4.3-7 in page 4-6 refers to a demonstration in section 4.2 ("it was shown ..."). There was no such demonstration in section 4.2; what is it?

268. 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 whatsoever on the dynamic response of the system. What exactly is the importance of the transit time? What is the basis for these comparative statements between transit times and filling up times?

269. 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 it depends on the flow and the flow depends on pressure and hydraulic heads, it is hardly a constant. Why is this transit time relevant? Is it perhaps an indirect way of assessing something else? What?

270. 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.

271. The second sentence on page 4-11 says "The volume fill time t_r is the natural scale for subsystems and processes where volume emptying or filling due to mass flows take place." While we ponder the case in which the volume fills or empties without the presence of mass flows, the filling time is not a "natural" characteristic of any vessel because it depends on the magnitude of the input flow. Since the input flow drives the

response of the vessel, the vessel is no longer an independent dynamic component and has no characteristic time of its own to contribute.

272. The report says that PANDA is "heavily instrumented with approximately 560 sensors" (page 5-7). This hardly qualified has "heavily instrumented" in a facility of that size. The real question is whether these 560 instruments are sufficient to provide a reliable (with built in redundancy and cross-checking) mass and energy balance of steam, water, and noncondensible gases in the facility during a test, that is consistent with the TRACG model nodalization of all components. Specifically address the effectiveness of the instrumentation in providing a conclusive and detailed representation of these quantities?

273. 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 has an effect in the long-term portion of the transient and whether the stored heat affects that long term noncondensible behavior. Provide some additional discussion of this test distortion beyond the scant paragraph 5.5.1.4..

274. 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? Furthermore, what are the results of the same comparison for the other facilities and the prototype? And what is the impact of these differences in their relative standing when it comes to validating the PIRT.

275. Page 5-2, first sentence - Does it really mean the tests or should it say the test facilities?

276. The last sentence on the top paragraph of page 5-2 is not a sentence at all.

277. The bottom paragraph on page 5-3 states that the depressurization created representative thermal-hydraulic conditions in the RPV of GIST. What is the basis for that statement?

278. 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 contradicts the statement about representative thermal-hydraulic conditions in the RPV, made only a few lines before. Where do these statements reconcile and how?

279. Page 5-5, second paragraph - Reference is made to section 3.5. This section does not exist in this report.

280. There are some discrepancies between the PI groups listed on page 6-2 and those derived in Appendix A of NEDC-32606P on page A-4. In particular, the term $\Delta M_{l,r}$ should be $\Delta M_{l,o}$. Please provide some appropriate clarification of nomenclature and definitions in order to resolve these discrepancies.

281. Equation 6.1-3 is incorrect. The last term on the right hand side is inconsistent with the formulation provided in NEDC-32288P, page B-12, Equation (B.2-22).

282. The elimination of the PCCS pool from the scaling considerations as the ultimate sinks has some significant implications. One clear implication of this approach is the pseudo-resolution of the noncondensible issue. Specifically, consider the statement on page 6-6: "Therefore the change in condensible fraction setting which will bound the range that would occur after a VB opening moves noncondensibles to the DW and then back to the WW". The fundamental reason to conduct PANDA testing is indeed to resolve the noncondensible issue after the opening of VB's. The implication of the extent of mixing or segregation bears immediate consequences on the PCCS operation and therefore on the heat removal from the containment. Setting a "bounding" value appears quite arbitrary. How is this justified?

283. In the proposed scaling the condensation phenomena are eliminated by considering a flow of steam and noncondensibles at the PCCS inlet as if this flow was not determined by the condensation rates within the PCCS. Note that the condensation rate is the direct result of the presence of noncondensibles. The proposed scaling approach misses completely this important point. The implication of this oversight 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 detailed technical justification for this simplification of your scaling approach.

284. 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? And if they are not fixed, what is the rationale to use a variable value as a reference and where do we get the number? The same question applies to the statements of the first paragraph on page 6-6.

285. 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?

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

287. 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, even with the subsequent paragraphs, 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 or unimportant (quantitatively and in terms of PIs) are other competing processes during each phase?

288. 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".

289. 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. Here the energy lost at 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 becomes apparent that the preoccupation with 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 oversight will be given in the comments concerning Section 8. Could you provide some clear description of what are the gauges by which the facilities are evaluated? Missing this opportunity results in the unsubstantiated criterion for a well scaled test facility presented in the next section.

290. The in-vessel, natural-circulation phenomena are not addressed in detail. On page 7-10, flashing is mentioned. This element of the vapor generation formulation is not clearly documented particularly in reference to the overall conditions in the RPV. The novel geometry of the RPV and its effects on the liquid inventory distribution may have a significant impact on these phenomena. How is this reflected in the scaling groups?

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

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

293. With reference to the discussion concerning the relationship between pressure and inventory, Figure 8-5 shows excellent agreement in the temporal behavior of the pressure. This result should be directly related to the liquid inventory information depicted in Figure 8-2. Here, during the crucial GDCS phase, the liquid mass results are most disturbing: Giraffe/SIT exhibits three times the magnitude of ESBWR and GIST about one third. This may well mean that neither facility represents the ESBWR. How can one explain that this is an acceptable outcome (beyond establishing an arbitrary bound that incidentally matches exactly this particular range of distortions)?

294. Chapters 6 and 7 discuss the non-dimensionalization of the governing equations and the comparative analysis of the resulting PIs. However, the actual comparisons, in figures 7.1 through 7.7 and 8.1 to 8.7, only have one equation per transient phase. What happened to the other dynamic equations?

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

RAIs for ESBWR Test Report, NEDC-33081P

296. Page 2-1, Section 2.2 - In ESBWR Test and Analysis Program Description, (NEDC-33079P) it is stated that the main vents will not open following the blowdown phase. In the PANDA tests, however, the main vents open on a number of occasions. It would be helpful to provide a section that describes the intended typicality and conservatisms in each of the tests and the particular aspects that dominate the results in terms of causing the main vents to open when they do.

297. Page 2-4, Section 2.3.5 - It is stated that, "To cover this possibility in Test P6, the IC was valved out of service after seven hours of operation." Why seven hours? It would seem that a value closer to one hour would be more appropriate to cover this eventuality.

Request for Additional Information (RAI)
TRACG Application for ESBWR Containment DBA Analyses
ESBWR Pre-Application Review
General Electric Company

298. On page 3-20 of NEDC-33083P, "TRACG Application for ESBWR," General Electric (GE) states that because of the limited ability of TRACG to model condensation on horizontal surfaces, part of the diaphragm floor is included in the vent wall heat slab. Mass and heat transfer from horizontal structures differs from mass and heat transfer on vertical structures. Lumping the structures may also effect the definition of the characteristic length used to determine whether the mass and heat transfer process in laminar or turbulent. Describe how the combined heat structure was created, including a discussion of the physical properties (materials, thickness, etc.) and the Biot number (the measure of the thermal internal resistance to the surface film resistance) for each structure and the combined structure to support this model. Provide justification that this model is conservative for this purpose.

299. On page 3-21 of NEDC-33083P, GE states that certain regions with dead end connections were eliminated but their volumes maintained in the overall model. This was done to address difficulties in TRACG to control the release of noncondensables from these regions. Describe these regions (general location, size, volume, flow path areas, etc.). Are the heat structures associated with these regions included in the model? The licensing calculations are based on a uniform relative humidity in the drywell, with a lower bound value to maximize the noncondensable gases present at the start of the analysis. Are these regions large enough and isolated (by flow restrictions) such that the relative humidity in these regions could be less than the average resulting in a large inventory of noncondensables gases which could be transported to the wetwell?

300. In Table 3.4-1 of NEDC-33083P, phenomena identification and ranking (PIRT) phenomena DW1 and DW4 are identified as "Insensitive." How were these determination 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.)

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

302. In NEDC-32725P, PIRT phenomena "XC7 - Early Containment Response" is identified as a high ranked phenomena under "Systems Interactions." XC7 is not identified in Table 3.4-1 of NEDC-33083P, or in Table 2.3-2 of "ESBWR Test and Analysis Program Description, "NEDC-33079P, August 2002. Provide a discussion for XC7 as it relates to the ESBWR including a justification that the TRACG modeling for the early containment

response is treated in a conservative manner and that the conditions at the end of blowdown are appropriate for the evaluation of the long term response evaluation.

303. A large temperature differential between wetwell level 7 ring 5 and ring 6 is maintained over the long-term, while at level 6 there is a small differential temperature (Fig. 3.7-8 and 3.7-14, NEDC-33083P). Explain the mass and heat transport processes in TRACG which sustain this differential temperature. Are there integral or separate effects test which show this sustained differential temperature?

304. In the PANDA tests (Section 5.7 of NEDC-32725P) it was noted that there was little or no axial stratification in the drywell. However, the TRACG models maintains stratification over the long-term, out to 48 hours (Fig. 3.7-3, NEDC-33083P).

(a) Explain the mass and heat transport processes in TRACG which sustain this axial stratification. Are there integral or separate effects test which show this sustained axial stratification? How would complete mixing effect the calculated performance on the passive containment cooling system (PCCS) and the containment response to the main steam line break (MSLB) (maintaining a high level of noncondensables near the PCCS inlet)?

(b) Provide a figure similar to Fig. 3.7-3 for the bounding case analysis.

305. Figure 6.6-16 in the TRACG Mcdel Description reports uses the units "WALLS/m^2K" for the average heat transfer coefficient. Should this be "watts/m^2-K?"

306. Equation 6.5-28 in NEDE-32176P is used for mass and heat exchange at a free surface, and is reported to be taken from "Heat Transfer," Third Edition, J.P. Holman.

(a) Provide the specific text (page) in Holman from which the equation is taken, or provide its derivation. Discuss the units as this form does not appear to be consistent with standard formulations.

(b) How was the Sparrow-Uchida degradation factor obtained? Does the correction factor include any bias based on the Sparrow or Uchida data - is it a "best-estimate" correction? What is the uncertainty in this correction factor and is it considered for licensing calculations?

307. In NEDE-32176P, Rev 1, it is stated that "If the containment contains significant amounts of horizontal surface area, care should be taken to model this area with a non-horizontal equivalent area since no condensation heat transfer will be predicted using $g^*\cos(0^o) = 0.0$."

(a) For the ESBWR, is this a concern? If so, how are horizontal surfaces treated for licensing calculations? Provide a description of the heat structures (wall, piping, etc.) considered in the licensing calculations in the drywell, the suppression pool and the wetwell and the mass and heat transfer correlations being used for condensation, convection and, if appropriate, radiation (based on the expected flow regime - laminar or turbulent, and orientation - vertical or horizontal). Identify the horizontal surfaces that are being treated as non-horizontal.

(b) In Section 7.11, it is stated that the Uchida correlation is available as an option for a lower bound for condensation, which would be consistent with guidance provided in Standard Review Plan. Is this option used for licencing calculations?

308. In NEDE-32176P, Rev. 1, it is stated that wall friction correlations are used in the same way as in other codes, like GOTHIC "which are specifically meant for containment analysis, and have been expensively qualified for these applications." Provide a reference to the qualification of the TRACG 3-D treatment of wall friction for containment calculations. In addition, it appears that the modeling in TRACG is based on a presumed flow pattern (ref. Fig. 6.2-1) which is reflected in the nodalization. It is also stated that when large 3-D cells are used, the error could be larger when using the fully developed flow correlations. Only one comparison is made for two cells of approximately equal size based on an assessment of the Reynolds number. The basic data used to develop the models is based on flow in pipes with diameters in the range of a few to several millimeters, or flow in rod bundles. Based on these observations is the treatment of wall friction on containment surfaces modeled in a conservative manner? Provide a justification for applying the models to these surfaces. How does the error in the wall friction influence the integrated system response, keeping in mind that there are several models used for containment which have errors or uncertainties identified with them?

309. Provide plots similar to Figures 3.7-2 through 3.7-15 in Section 3 of NEDC-33083P for the ECCS/LOCA calculations presented in Section 2 of NEDC-33083P (time frame 0 to 2000 seconds). This will provide a means to assess modeling differences, if they exist, between the modeling of containment for core performance versus the modeling of containment for containment performance.

310. Provide plots similar to Figures 3-7-2 through 3.7-15 in Section 3 of NEDC-33083P but for the time frame 0 to 500 seconds and for the time frame 0 to 3600 seconds. This will provide a means to assess the containment modeling on the short term (blowdown and early gravity driven cooling system (GDCS) injection periods).

311. Provide a table of the mass flow rate (kg/sec) and energy (J/sec) from the MSLB pipe break into the drywell for the base case (Section 3.7.2 of NEDC-33083P) and the bounding case (Section 3.7.3 of NEDC-33083P). The time between data points should be sufficiently small (such that integrating the tabular data would match the integrated values at the time of GDCS injection, and to capture the timing of the suppression pool vents opening and closing) to be useful in performing a CONTAIN audit analysis of the blowdown portion of the accident (data to the onset of GDCS flow is adequate). Also provide the average reactor pressure vessel conditions at the start of GDCS injection - water inventory, steam inventory, average pressure and average temperature, and the times of each trip signal up to GDCS injection.

312. Flow Regime Maps

The flow regime maps provide the critical information about the interfacial area density and the shape for the two-fluid formulation.

The ESBWR containment consists of many regions where two-phase flow conditions exist. These regions vary in size and orientation. The drywell and suppression chamber (wetwell) consists of large volumes which may have a condensate film on the walls and droplets in the gas phase. The suppression pool receives an inflow from a jet mixture of noncondensable gas and steam which will break-up in bubbles. There are also other liquid pools with free surfaces. The horizontal vents undergo vent clearing and two-phase flow during early blowdown. The heat exchangers of the PCCS have small diameter tubes with downward film flow on the wall.

The transition between annular flow and dispersed flow regimes is defined by entrainment inception. However, no information about entrainment inception is provided in NEDE-32176P. The entrainment rate correlation described in the report, is based on pipe data with diameters less than 0.032 m and, therefore, the entrainment correlation does not appear to apply to any part of the containment except the PCCS tubes.

A liquid film is expected on the heat structures and liquid droplets in the drywell atmosphere. However, the droplet field can not be predicted by the entrainment criteria in the code as the mechanism is fogging and not shear at the interface. Therefore, the flow regime map does not appear to apply to the drywell and suppression chamber.

(a) Justify the use of the flow regime map for calculating flows (velocities) near containment surfaces and for intercell flow between the large, 3-D cells used to model the containment volumes. It appears that the nodalization drives the determination of flow regimes and that there could be an inconsistence description of the flow regime (and cell fluid properties) at a 3-D cell boundary which does not represent a physical structure.

(b) Describe the model for entrainment inception from films on the containment walls.

(c) There is also a question about the applicability of the pipe flow regime map to the drywell, the suppression chamber (wetwell), the suppression pool and to the downward flow in the PCCS tubes and return lines and the vertical sections of the horizontal vents. The Tables 6.1-1 and 6.2-1 (NEDE-32176P, Rev 1) summarize GE's assessment of flow regime maps for different containment regions. The indirect assessment through interfacial shear and mass transfer data base covers the pressure, void fraction and mass flux range, but the diameter range is not covered for the drywell and suppression chamber and there is a large ("by about 15%") uncertainty in applying the correlations to these volumes.

How is this uncertainty treated in licensing calculations? How was the uncertainty value obtained and could it be larger? How does the uncertainty in the interfacial shear and mass transfer influence the integrated system response, keeping in mind that there are several models used for containment which have errors or uncertainties identified with them?

313. Wall Friction

Wall friction and momentum transfer is important in the PCCS tubes and the horizontal vents. The friction on the containment walls is also computed in the code. The single phase friction factors are calculated from the curve fit to Moody's diagram which is valid for pipe flows. The data base covers a very large Reynolds number range. However, the applicability to the drywell geometry and large diameter channels is questionable. This model was assessed with the data base limited to small diameters, which covers the PCCS tubes, but is too small for horizontal vent. Furthermore, the two phase multipliers were based on the data with lower steam qualities while in the drywell and in the horizontal vents, the quality could be close to 100%. Furthermore, it is not clear if the two-phase multiplier is valid for down flow as expected in the PCCS tubes and in the horizontal vents.

(a) Provide justification for using this model for the PCCS tubes, the horizontal vents and the containment wall structures.

(b) There is another uncertainty in the implementation of the friction factors in the 3-D component used for containment. It is not clear how the friction factor in the transverse direction are estimated from the Moody's curve which was developed from vertical tube flows.

How is the traverse friction factor obtained for use in the large 3-D cells? How is friction handled on horizontal surfaces, for example the drywell floor or the diaphragm floor?

(c) An additional uncertainty is in the partitioning of the wall friction contribution between two phases. The correlations for single phase flow along with two-phase multiplier are for mixture models and are being used for two-fluid formulations. The report does not indicate the method used to dividing wall friction between the two phases.

Describe the method (model) for dividing the wall friction between the two phases.

314. Wall Heat Transfer

Wall heat transfer occurs in every component in the containment. The important areas are heat transfer to vertical and horizontal structures and inside and outside of the PCCS tubes.

The single phase heat transfer is based on Dittus-Boelter for forced flow and McAdams correlation for free convection on vertical walls. However, applicability of these correlations for large open spaces has not been shown.

The Dittus-Boelter correlation was developed from pipe data and requires the hydraulic diameter for the Reynolds (Re) number calculation. Similarly, the McAdam's correlation also requires the hydraulic diameter for computing the Grashof (Gr) number. These correlations have been implemented with hydraulic diameter based on cell size. If the

cell hydraulic diameter is computed with only the wetted perimeter, the hydraulic diameter may be correct.

(a) Provide a justification for using these correlations for the containment surfaces. It would be more appropriate to use correlations for flat plates which are based on wall length. Can it be shown that the use of an appropriately calculated hydraulic diameter to represent the structure characteristic length will result in a conservative heat transfer calculation? Will laminar conditions exist in the containment (for example based on Gr number) for which additional correlations would be needed? In this case, or if a correlation for a flat plate were to be used to better represent the structure, the hydraulic diameter (characteristic length) would not necessarily cancel out based on a $Gr^{1/3}$ correlation.

(b) The correlations used to model heat transfer require an estimate of the Reynolds number, but it is not shown how it is estimated. For the 3-D formulation, there are three components of velocity and the code document does not indicate which component of the velocity is used to estimate the Reynolds number. The other uncertainty is in the use of the cell edge velocity. As the cells are large, the velocity is averaged over a large area and the effect of a no slip condition at the wall is negligible. The correlations were developed from pipe flow data where the average velocity is affected much more by the no slip condition at the wall. Furthermore, the wall heat transfer is partitioned between two phases but it is not explained how this partitioning is performed.

How is the Reynolds number obtained for use in these correlations? How does the uncertainty in obtaining the Reynolds number influence the integrated system response, keeping in mind that there are several models used for containment which have errors or uncertainties identified with them?

(c) Describe the method (model) for dividing the heat transfer between the two phases.

(d) For horizontal surfaces, TRACG uses the same heat transfer correlation as for vertical walls. The assessment provided indicates that for large Gr x Pr, the heat transfer coefficient is significantly over predicted.

Provide an assessment of the effect of this discrepancy on the long term pressure calculation. How does the uncertainty in obtaining the heat transfer from horizontal surfaces influence the integrated system response, keeping in mind that there are several models used for containment which have errors or uncertainties identified with them?

(e) The heat transfer from a floor will be different than from a ceiling. This is not distinguished in the code. How is this difference treated in licensing calculations?

(f) The other area of importance is heat transfer due to condensation on cold surfaces. With the accumulation of noncondensables the condensation rate will degrade. TRACG models this heat transfer with the Nusselt's correlation for

condensation and degradation due to noncondensable through use of the minimum value from the Kuhn-Schrock-Peterson (K-S-P) correlation, which was derived from vertical pipe data, and the Uchida correlation. The data base for these correlations covers pressure up to 4.5 bars which is appropriate for containment application.

In principle, the staff accepts such an approach. However, the applicability of this model to the containment analysis needs to be discussed in more detail given the fact that the nodalization may affect the noncondensable concentration near the interface and therefore, the heat transfer degradation.

(g) How was the degradation factor obtained? Does the correction factor include any bias based on the data used to develop the degradation factor - is it a "best-estimate" correction? What is the uncertainty in this correction factor and is it considered for licensing calculations?

(h) The two-phase flow in the PCCS tubes is modeled with the conventional approach for a film flow regime. The critical aspect of this component is the heat transfer inside the tubes. The correlation used by TRACG for single phase flow and cpndensation heat transfer is appropriate as it was developed from tube data of the same diameter as the PCCS tube, and for pressures up to 5 bars.

However, implementation as described in Section 6.6.11.1 has an apparent error in Eq 6.6-60. The average heat transfer coefficient is a function of the length over which averaging was done and a derivative with respect to [z] should account for this dependency. This model should be revisited and if simplifying assumptions are being made, describe the derivation of the equation as presented.

315. Interfacial Momentum Transfer

Interfacial momentum transfer occurs at interfaces and affects the distribution of the liquid and vapor phases and therefore the void fraction. It is important to predict the void fraction accurately as it has an effect on heat transfer and the two-phase multipliers for wall friction and local pressure loss coefficients. The containment has many regions where interfacial momentum transfer needs to be modeled, such as the film on the wall (or the spillover from the vessel in the drywell), the droplet phase, the PCCS tube film flow, the flow in the horizontal vents and the flows over liquid surfaces in the GDCS tank, the suppression pool and the condensate pools that might be created in the drywell or other regions.

The general approach in TRACG is to use mixture information or a drift flux correlation and to partition it into interfacial shear for different regimes. The description lacks an assessment of the applicability of this approach to model the containment. The areas where the models may not be applicable include the drywell, the horizontal vents and the suppression pool. In the drywell area, the liquid will be in the form of films on structures and fog in the atmosphere. The flow regime maps will not predict a film flow and therefore, the code may select, for example, a dispersed flow regime. Furthermore, the fogging in the bulk due to the cooling of the steam will likely lead to a droplet flow

regime. However, the size of the drops should not be determined from a Weber number equal to 12 as this critical Weber number represents the largest drop size, while a fog will consists of much smaller drops. The fogging phenomenon will produce a spectrum of drop sizes which cannot be represented by a drop size calculated from the critical Weber number, and thus resulting in a different behavior of the droplets.

(a) Provide a discussion of the applicability of the TRACG models to address these issues for interfacial momentum transfer- void fraction, two phase multipliers for wall friction, drop formation and the treatment of drops, and interfacial momentum - as they relate to the evaluation of containment performance.

(b) The other area where the applicability of TRACG is not certain is in the horizontal vents as the interfacial shear was derived from vertical flow data and it may not apply to horizontal vents. No assessment has been presented for its application to the horizontal vent flows.

Provide a discussion of the applicability of the interfacial shear model in TRACG for the horizontal vents.

(c) The suppression pool receives a mixture of steam and noncondensables from different sources (horizontal vents, safety relief valves and PCCS). The steam condensation will depend upon the residence time of the bubble and the interfacial area. The report does recognize the difficulty of modeling the pools (see the text below Eq. 6.1-33, NEDE-32716P).

If the void fraction is over predicted, then the interfacial shear is under predicted and bubbles will have larger residence time and larger interfacial area leading to more condensation. It is recognized that the design philosophy for the vents to the suppression pool is such that 100% of the steam is condensed in the pool (no steam escapes the pool surface into the wetwell gas space).

TRACG handles the condensation of the steam in the suppression pool based on the Bubbly/Churn flow model described in Section 6.1.3 of NEDE-32716P, but does not account for degradation due to the presence of noncondensables. Are the expected conditions (pressure, hydraulic diameter and mass flow rate) within the range for which the model is applicable? Is it conservative to neglect the degradation from the presence of noncondensables? How is the over prediction of the void fraction addressed in licensing calculations?

(d) Is there any data and are there any TRACG comparisons to that data where the vent submergence was not low enough to prevent steam from escaping the pool?

316. Interfacial Heat and Mass Transfer

The heat and mass transfer at the interface are related and predictions of one will provide an estimate of the other. The model consists of predicting the flow regime, interfacial area density and heat transfer coefficients at the interface.

(a) It is our understanding that the liquid side interfacial heat transfer coefficient is obtained from a correlation developed for heat transfer over evaporating drops. Provide a description of the physical process being modeled and justify its use for this situation.

(b) It is our understanding that the vapor side interfacial heat transfer coefficient is obtained from the conduction heat transfer solution for a solid sphere with a correction for internal convection and the degradation due to noncondensables is accounted with the a degradation factor. If this is correct provide a description of the physical process being modeled and justify its use for this situation.

317. The TRACG containment models utilize the same conservation equations and constitutive correlations as applied to the reactor system models, i.e., the code, which was initially developed to model the primary side of BWRs, is currently being used to model the full plant including the containment. In addition, many of the models have identified errors and uncertainties associated with their use for the containment evaluation. Further the TRACG nodalization models are prescribed to account for additional shortcomings in TRACG to treat some important features, like mixing and stratification in the containment. Some of these prescribed models are based on expected performance (engineering judgement) or the results from small-scale experiment. Typically, containment codes are assessed against a large body of experimental tests (both separate effects and integral tests) designed to address containment performance. In addition, when a new code is proposed for use, an applicant provides a comparison to its currently acceptable code as a benchmark to aid in understanding the results and identifying important features or phenomena in the new methodology.

(a) Provide a plan and schedule to assess the ability of TRACG to model containment performance against integral tests. Integral tests that should be considered include the Marviken tests, the Carolinas Virginia Tube Reactor (CVTR) test 3 without sprays, and the Battelle-Frankfurt Model Containment (BFMC) tests C-13 and C-15 for main steam line breaks. The TRACG results should be assessed against available results from other computer program results (GOTHIC, CONTAIN, etc.).

(b) Provide a plan and schedule to assess the ability of TRACG to model containment performance against separate effect tests. Separate effects tests that should be considered include the Wisconsin Flat Plate condensation tests (Huhtiniemi, I.K. and Corradini, M.L., "Condensation in the Presence of Noncondensable Gases," Nuclear Engineering Design, 141, pp.429-446, 1993), M. Siddique, "The Effects of Noncondensable Gases on Steam Condensation Under Forced Convection Conditions," MIT, January 1992, and K. Liang, "Experimental and Analytical Study of Direct Contact Condensation of Steam and Water," MIT, May 1991. The TRACG results should be assessed against available results from other computer program results (GOTHIC, CONTAIN, etc.)

(c) Provide a plan and schedule to assess TRACG against the previously accepted GE codes used for containment performance evaluations, M3CPT and SHEX. These comparisons need not extend beyond the time of GDCS injection.