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*****, 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.

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.

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 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.

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

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

185. 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?

186. 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?

187. Page 2-5, Section 2.2.1.2 - 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).

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 location of 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 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?

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

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

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 typographical error in the fourth column, “CFD code calculations show sort [sic] 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) 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.

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

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

206. Page 3-3, Table 3.2-1 - There is a typographical error – “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 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?

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, what is the relevance of the section covering flow distribution in the chimney during reflood?

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 that “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) "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. Please correct this statement.

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 typographical error. "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 - Were any tests performed 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) 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 the basis for 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 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).”

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 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.

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 tube 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 that must be considered, such as wall penetrations 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. Question was addressed in July 9, 2003, meeting.

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].

<u>RAIs for ESBWR Scaling Report, NEDC-33082P, Revision 0</u>

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 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.

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 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?

256. 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?

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:

   1. The explicit representation of the condensation processes in the PCCS is the key element that links the system to its ultimate heat 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?

   2. The derivation of the vapor generation equation in Appendix B of NEDC-32288P, "SBWR Scaling Report," is referenced to the book of Lahey & Moody. In consulting the reference, there is no trace of such equation. Please provide a detailed basis for the derivation of this crucial result, including any assumptions.

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

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

262. The RPV liquid mass equation is derived in Appendix A. The derivation relies on the vapor generation formulation. 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 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. 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 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.

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 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?

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 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?

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." The fill 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. Please clarify your statement in light of the volume fill time not being a truly natural time scale.

272. The report says that PANDA is "heavily instrumented with approximately 560 sensors" (page 5-7). However, it is not clear 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. 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 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.

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? 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?

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

276. The last sentence on the top paragraph of page 5-2 is not clear and should be revised.

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 paragraph seems to contradict the statement a few lines before about representative thermal-hydraulic conditions in the RPV. Please reconcile these statements reconcile.

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, "SBWR Testing Summary Report," on page A-4. For example, the term $\Delta M_{l,r}$ should be $\Delta M_{l,o}$. Please clarify the 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, "SBWR Scaling Report," page B-12, Equation (B.2-22).

282. The elimination of the PCCS pool from the scaling considerations as the ultimate heat sinks has some significant implications. One implication of this approach is the resolution of the noncondensible gas 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 noncondensible gases to the DW and then back to the WW". The fundamental reason to conduct PANDA testing is to resolve the noncondensible gas issue after the opening of VB's. The implication of the extent of mixing or segregation affects the PCCS operation and therefore heat removal from the containment. Setting a "bounding" value appears arbitrary. How is this justified?

283. 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.

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? 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.

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

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 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?

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, 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.

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 effect reflected in the scaling groups?

291. 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?

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. If the figure of merit is core coolability, it is necessary to show that when a given non-dimensional group is within the acceptability range, its effect on core coolability is within the acceptable range of uncertainties. Describe what figure of merit is used and provide a detailed justification on the acceptance criterion based on the impact that the distortions of important parameters have on the figure of merit.

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 do not appear to be consistent: Giraffe/SIT exhibits three times the magnitude of liquid mass as ESBWR and GIST about one third. Explain why this is an acceptable outcome.

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. However, the discrepancies in the RPV liquid inventory recovery are more significant. How can these concluding remarks be tied to the overall discussion on the acceptable range of the distortions outlined in Section 8 of the report?

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 was this time chosen? It would seem that a value closer to one hour would be more appropriate to cover this eventuality.