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MFN No. 113-94
Docket STN 52-004

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington DC 20555

Attention: Richard W. Borchardt, Director
Standardization Project Directorate

Subject: Responses to the Referenced Letters

References: 1) Letter, M. Malloy (NRC) P. W. Marriott (GE), *SCHEDULE FOR REVIEW OF TEST AN ALYSIS PROGRAM DESCRIPTION (NEDC-32391P) FOR TH NUCLEAR ENERGY (GE) SIMPLIFIED BOILING WATER REACTOR (SBWR) AND INITIAL REQUESTS FOR ADDITIONAL INFORMATION (Q900.65-Q900.81 AND PURDUE UNIVERSITY QUESTIONS - SET 5)*, dated September 12, 1994.

2. Letter, M. Malloy (NRC) to P. W. Marriott (GE), *REQUESTS FOR ADDITIONAL INFORMATION REGARDING THE TEST PROGRAM FOR THE GE NUCLEAR ENERGY (GE) SIMPLIFIED BOILING WATER REACTOR (SBWR) (Q900.82-Q900.95)*, dated September 16, 1994.

The Enclosures to this letter contain responses to Requests for Additional Information (RAIs) 900.65 - 900.81, Purdue University Questions - Set 5 (Questions 1, 2, and 3), and 900.83, 900.87, 900.91, 900.93, and 900.94, which were enclosures to the Referenced letters.

Sincerely,

TR M'Intyre

T. R. McIntyre, Acting Manager
Advanced Plant Technologies

Enclosures: 1. Responses to Reference 1.
2. Responses to Reference 2.

cc: P. A. Boehnert (ACRS)
R. W. Hasselberg (NRC)
M. Malloy (NRC)

Enclosure 1 to MFN 113-94

RAI Number 900.65

Question:

Resubmit NEDC-32391P, "SBWR Test and Analysis Program Description," with clear identification of the proprietary information on each page sought to be withheld, along with the reasons for withholding the information. Consistent with the staff's April 7, 1994, letter from D. Crutchfield to P. Marriott regarding the quality of the SBWR application, submit a non-proprietary version of the report within a reasonable period of time of the proprietary version, if the versions are not submitted simultaneously. Both versions of the report should be resubmitted as Revision 0 in lieu of a draft.

In the letter(s) transmitting the report, provide a page-by-page summary of any additions and corrections made to the report since the August 10, 1994, version was submitted to the staff for review.

GE Response:

NEDC-32391P, "SBWR Test and Analysis Program Description," Revision A, with clear identification of the proprietary information on each page sought to be withheld was transmitted by MFN 109-94, dated September 15, 1994. The letter transmitting the report provided a page-by-page summary of additions and corrections made to the report. A non-proprietary version entitled "SBWR Test and Analysis Program Description," NEDO-32391, was transmitted by MFN 110-94, dated September 15, 1994.

RAI Number 900.66

Question:

Provide a point-by-point response to the staff's March 7, 1994, letter from D. Crutchfield to P. Marriott regarding concerns about the SBWR testing program. Alternatively, provide a road map that identifies where in NEDC-32391P, "SBWR Test and Analysis Program Description," each of the concerns of the March 7, 1994, letter are explicitly addressed.

GE Response:

Issue
Acceptability of the Gravity Driven Cooling System (GDCS) Integral Systems Test (GIST) program data as the sole integral experimental basis for SBWR in view of the differences in configuration compared to the current SBWR design.

Response
While the physical configuration of GIST is representative of the 1988 SBWR design, GE considers that GIST provides GDCS performance data suitable for TRACG qualification. The basis for this statement is given below.

The principal difference between GIST and the current SBWR design is that the GDCS pool is a separate entity in the drywell instead of being a part of the suppression pool. This difference notwithstanding, the test captures the interactions between multiple regions represented by the reactor vessel, drywell and wetwell. The interactions between RPV depressurization and the GDCS are properly represented. The scaling study in Appendix B of NEDC-32391P demonstrates that the major parameters governing depressurization rate and driving heads for GDCS flow are preserved even though there are differences in the configuration of GIST from the current SBWR design

Testing in GIST is intended to simulate the late blowdown/early GDCS phase of the LOCA transient (Fig. 5.3.1 of NEDC-32391P), and thereby provide data for TRACG qualification of GDCS performance. The parameters of primary interest are: System pressure response which determines the timing of GDCS initiation, GDCS flow and RPV level response.

No scaling distortions have been identified in the significant phenomena which would preclude the use of the GIST data for their intended application

It should also be noted that the GIST data are supplemented by data from other BWR LOCA integral test facilities (TLTA, FIST) for the early part of the blowdown.

Issue
Absence of components/systems that could interact (IC, PCCS)

Response
GIST simulates the limiting LOCA transient without credit for the IC. No credit is taken in LOCA analysis for the IC.

Analysis shows (NEDC-32391P, Appendix C) that the IC increases the minimum water level for the limiting breaks (bottom break and GDCS line break). For the steam line and feedwater line breaks, the minimum water level is lowered due to void collapse. However, for these breaks the minimum water level is several meters above the top of the core and the impact is not significant to safety. Furthermore, postulated interactions between the IC and DPV resulting in flow reversal in the IC and subsequent reduction in the depressurization rate are shown not to be possible (NEDC-32391P, Appendix C). Thus, the overall impact of the IC is to increase the margins for the limiting breaks.

Because a relatively small fraction of the drywell to wetwell flow passes through the PCCS in the blowdown period, the PCCS has a minimal effect on the drywell pressure and GDCS flow(NEDC-32391P, Appendix C). The absence of a PCCS in the GIST tests has little or no effect on the vessel transient.

Interactions between the PCCS and GDCS are important in the containment during the GDCS phase of the transient in that they can result in vacuum breaker opening. This leads to a return of the noncondensibles to the drywell and subsequent recycling through the PCCS. Tests are planned in PANDA Phase 2 to address these interactions.

Issue
Insufficient characterization of GIST facility thermal hydraulic behavior

Response
GE agrees that calibration data on pressure drops and heat losses would be desirable. However, the data are adequate for the intended application.
For the TRACG calculations, the pipes, valves, elbows and orifices were treated as standard hydraulic components. The pressure drops and pressure distributions were calculated based on handbook published loss coefficients (Idelchik, Crane). Based on these assumptions, TRACG calculated the GIST transient response satisfactorily. This confirms the previous good experience with this approach.

Critical flow through the SRVs and the break is based on the minimum flow area. The TRACG model for critical flow, which has been qualified over a wide range of data (NEDC-32391P, Table 5.1-1) was employed for the calculation of critical flow.

Heat losses were calculated based on reasonable analytical values for the natural convection heat transfer coefficient. A sensitivity study on the heat transfer coefficient (variation of heat loss by a factor of 2) showed very little sensitivity to this parameter.

Issue
Lack of a quantitative scaling study

Response
A quantitative scaling study has been performed and is provided in NEDC-32391P, Appendix B, Attachment B1.

Issue
Requirement for additional data from PANDA to be included as part of the testing for design certification. Details of the test matrix and facility scaling to be provided to the NRC.

Response
GE agrees that PANDA data will be used as primary data for TRACG qualification. The test/qualification matrix and facility scaling are provided in NEDC-32391P.

Issue
Requirement for Isolation Condenser performance data from PANTHERS to be included as part of the testing for design certification, if credit is taken for the IC.

Response
GE agrees that PANTHERS thermal hydraulic performance data will be used for TRACG qualification. The test/qualification matrix and facility scaling are provided in NEDC-32391P. While no credit is taken for ICs in LOCA analysis, interaction studies have shown no deleterious effects if ICs were to operate (NEDC-32391P Appendix C).

Issue
Requirement for data demonstrating PCCS performance in the presence of light noncondensible gases in an integral system test.

Response
A combination of tests and analysis addresses the effects of light noncondensibles (hydrogen) on the PCCS performance and containment pressure.

One of the major concerns underlying the light noncondensible gas issue is the capability of the PCCS to restart after the drywell and PCCS have been filled up with noncondensibles. A Noncondensible Blanketing Test (M7) is planned in PANDA Phase 2 to address this issue. Whether the noncondensible gas is lighter or heavier than steam does not make any difference for this demonstration, because it shows that the PCCS can purge the noncondensibles.

At a component level, tests will be performed at PANTHERS to determine the effect of helium buildup in the full scale PCC units. With the vent blocked, the helium will accumulate in the PCCS, and the distribution of helium and the effect on heat removal capacity can be determined.

A helium system response test program in GIRAFFE has been added as described in the response to RAI 900.67.

The effect of the hydrogen resulting from 100% metal-water reaction on the integral system response can be bounded through calculations.

Issue
Availability of experimental and facility data for tests run by others for GE (GIRAFFE, PANDA, PANTHERS).

Response
GE will continue to provide the requested information or provide NRC access to the test facilities and/or test performers.

Issue
Requirement for documentation of testing program in conformance with 10CFR52.47 in Section 1.5 of SSAR.

Response
GE agrees to include a summary of the testing program in SSAR Section 1.5 and/or a reference to NEDO-32391.

Issue
Need for additional test in properly scaled integral test facility.

Response
A systematic study of test and analysis needs has been performed in NEDC-32391P. A need for additional testing has been identified in PANDA for specific interactions between the GDCS and PCCS in the GDCS phase resulting in vacuum breaker openings, for interactions with ICs, and to demonstrate PCCS restart when filled with noncondensible.

(Tests M5 - M9). These tests have been added to PANDA Phase 2 testing. Scaling of PANDA is judged to be adequate for its intended purpose and is addressed in Appendix B of NEDC-32391P.

The GIST tests are adequate for validating vessel performance during the late blowdown/early GDCS phase. Here there are few uncertainties and large margins to core heatup. The overall coverage of the LOCA transient by the integral tests is shown in Figure 5.3-1 of NEDC-32391P.

RAI Number 900.67

Question:

GE's July 1, 1994, letter (MFN No. 087-94) states that GIRAFFE tests were development tests and GE intends to use GIRAFFE data to substantiate the results of PANDA and PANTHERS at another scale. Contrary to this position, NEDC-32391P, "SBWR Test and Analysis Program Description," indicates that the helium test data from GIRAFFE are to be used as part of the TRACG qualification effort. GE needs to clarify the use of helium test data from GIRAFFE vis-à-vis the position on GIRAFFE data stated in MFN No. 087-94, in particular:

(a) Is the GIRAFFE helium test the only one, or are there plans for other helium tests, in GIRAFFE or in another test facility?

(b) If helium test data from GIRAFFE only is to be used, how will GE resolve the quality assurance concerns raised by the staff on other GIRAFFE tests during its June 21-23, 1994, inspection?

(c) The recently conducted GIRAFFE helium test contained only helium. Explain whether future tests will be more typical of post-accident conditions, include a combination of helium and nitrogen. In addition, the test duration should be based on observing at least one purge and transient back to steady state operation of the Passive Containment Cooling System (PCCS).

GE Response:

(a) Since the submittal of NEDC-32319P in mid-August, GE has been pursuing negotiations with Toshiba Corporation regarding additional helium testing in GIRAFFE. These negotiations have recently been concluded. As a result of this agreement, reference to the existing GIRAFFE helium test will be removed from NEDC-32391P, and a new test program will be performed in GIRAFFE specifically to address the staff's concerns relative to lighter-than-steam non-condensable gasses in the SBWR. Facility configuration and instrumentation will be similar to the GIRAFFE Phase 2 Main Steam Line Break tests. The test objectives of the GIRAFFE Helium Test Program are:

1. Provide data that demonstrate the effective operation of the passive containment cooling system with the presence of a lighter-than-steam non-condensable gas, and

2. Provide data for qualification of containment response predictions by TRACG in the presence of lighter-than-steam non-condensable gases.

Four test conditions will be included. Test Condition H1 will be a base case with nominal initial conditions the same as in PANDA tests M3 and M4, e.g., near SBWR SSAR LOCA conditions one hour into the accident scenario. The drywell will contain a mixture of steam and nitrogen at a total pressure of approximately 300 kPa. Test H2 will be a nominal repeat of test H1, but with a helium replacing the total volume of nitrogen in the drywell and PCCS. Test H3 will have the same total initial drywell pressure as tests H1 and H2, but with the initial non-condensable fraction consisting of helium / nitrogen mixture having the same proportions that would result from a 100% SBWR metal water reaction. Test H4 will start with the same initial conditions as test H1, (nitrogen and steam in the drywell), and will have constant helium injection to the drywell. The helium addition rate will be such that the helium is injected over a period of one hour, and the test will be terminated when the total mass of helium added is equal to the initial drywell helium mass in Test H3. The test will be continued to observe the venting of any residual helium from the drywell following termination of helium injection.

System response from the four tests will be compared with each other to establish the effects of lighter than steam, or a mixture of lighter-than-steam and heavier-than-steam non-condensables, on the effectiveness of heat rejection by the PCC heat exchanger. Specific test conditions are currently being finalized. No other helium testing in a facility other than GIRAFFE is planned

(b) The new GIRAFFE HELIUM tests described in response to item (a), above, will be performed by Toshiba in accordance with Japanese National Standard JEAG-4101 (1990 Rev.) GE has reviewed this standard, and concluded that in all important aspects, it meets the intent of 10CFR50 Appendix B and ANSI/ASME NQA-1 (1983). GE requests that the staff review this standard for this application, and concur that tests performed under it are acceptable for the application of this data to the SBWR. GE effort supporting the new GIRAFFE testing will be performed under our own, NRC accepted, QA program.

In addition to the four GIRAFFE Helium tests described in Response (a), Toshiba will also be performing a repeat of the GIRAFFE Phase 2 Main Steam Line Test, one of the two tests described as GIRAFFE Data Group G2 in NEDC-32391P. This test will be performed using the above quality assurance requirements, and will be performed in order to reinforce ("tie-back") the validity of previous GIRAFFE testing with the NRC staff.

(c) We believe the GIRAFFE Helium test program as defined in the response to item (a) is responsive to the staff's comments as elucidated in this item.

RAI Number 900.68

Question:

Both the staff (during a meeting with GE on August 18, 1994) and the ACRS Thermal-Hydraulic Phenomena Subcommittee (during a meeting on August 24, 1994) have expressed concerns regarding test instrumentation. In general, GE seems to place dependence on a limited number of pressure-temperature measurements, and then back-calculate any local conditions of interest. Specifically, the staff is concerned with:

(a) lack of direct local heat fluxes in the PCCS heat exchangers,

(b) lack of direct measurements of the pressure and/or noncondensable gas distribution along the PCCS heat exchanger tubes,

(c) lack of direct measurements of local concentration of noncondensable gases.

Address the above concerns regarding adequacy of test instrumentation for PANDA and PANTHERS.

GE Response:

(a) SIET Document 00157ST92 Rev 1, transmitted to the NRC by MFN No. 086-94 dated June 30, 1994, in response to RAI 950.24, addresses the instrumentation specifically added to the PANTHERS PCC heat exchanger in order to address the ACRS concerns on local heat flux measurement. Figure A.2.1 of the SIET document shows the location and type of instrumentation for local heat flux measurement.

Briefly, 72 thermocouples were added to the PANTHERS test instrumentation to address the ACRS concern. Four PCCS tubes, located at differing locations within the tube bundle, have been instrumented at nine elevations each. Thermocouples are located on the inside and the outside of the tubes, so that local heat fluxes may be calculated from the temperature difference across the tube wall. The algorithm to be used in data analysis is given in SIET document 00098PP91 Rev. 1, transmitted to the NRC by MFN No. 098-95 dated August 16, 1994.

(b) It is true that there are no direct measurements of the pressure or non-condensable gas concentration along the PCC heat exchanger tubes. We have evaluated this situation, and determined that such measurements are not necessary to determine the location within the tubes where condensation is taking place. Temperature measurements along the PCCS tubes were used successfully in GIRAFFE to determine the location of the condensation process within the PCC heat exchanger tubes, and review of

initial PANTHERS data likewise has confirmed this capability. Pressure difference measurements between the upper and lower headers of the PANTHERS PCCS have indicated very low pressure drop through the units.

(c) In PANTHERS, which is a steady state experiment, both the air and steam flow to the heat exchangers are measured, and controlled as an independent condition of the experiment. GE has also committed to provide local non-condensable measurements in the PANDA drywell. Our current plan is to determine the non-condensable concentration distribution by use of a combination of temperature measurements and oxygen sensors located at several locations in the PANDA drywell.

RAI Number 900.69

Question:

Adequacy of scaling, phenomena level versus systems interaction: During a meeting regarding the SBWR test and analysis program on August 24, 1994, the ACRS Thermal-Hydraulic Phenomena Subcommittee expressed concerns about whether preserving parameters like gravity head and local friction losses is sufficient to model an integral system behavior. For example, having a "tall and skinny" test facility may affect the 3-dimensional distribution of noncondensable gases. Another example is that inappropriate modeling of global inertia terms may distort the integral system responses, like pressure and water level oscillations. In the scaling analyses, did GE include these "integral" or "global" effects?

GE Response:

GE has included these effects, as noted below:

Scaling of the Global Inertia Terms in the Momentum Equation

In the top-down scaling analysis presented in NEDC-32288 (Section 2.3), the transfers of mass driven by pressure differences were considered using the momentum equation integrated over a segment (piping) length. A rigorous analysis led to Eq. (2.31) of NEDC-32288 where a number of non-dimensional groups appeared. The non-dimensional number multiplying the rate of change of the velocity is Π_{in} (Eq. 2.32 of NEDC-32288),

$$\Pi_{in} = \frac{\rho^{\sigma} L_I u_r^o / \tau_{tp}^o}{\Delta p^o}$$

which scales the inertial pressure drop with respect to the reference pressure drop. Considering the transit time of the fluid in the piping, P_{in} can be replaced by an alternative form, Eq. (2.37) of NEDC-32288,

$$\Pi_{in} = \frac{\rho^o u_r^{o2}}{\Delta p^o}$$

and the ratio of the equivalent inertia to volume lengths, L_I/L_V, Eq. (2.42).

$$\frac{L_I}{L_V} = \frac{\sum \frac{a_r}{a_n} l_n}{\sum \frac{a_n}{a_r} l_n}$$

The inertia number and the ratio L_I/L_V were considered in Appendix B of NEDC-32391P on Scaling Applicability (Tables B1-9 to B1-11 for GIST; B1-22 to B1-27 for GIRAFFE; B1-39 to B1-46 for PANDA). The L_I/L_V ratios of the prototype and of the various experimental facilities are matched reasonably well. Although the experimental facility components often have different Π_{in} values than the ones of the prototype (due to differences in the flow velocities in these components), this is a very minor scaling distortion, since the relative importance of the inertial pressure drops with respect to the system response is very small. Inertial pressure drops can reach significant magnitudes only during rapid system transients when velocities change abrupty; this is not the case during SBWR transients, except during the very first moments of depressurization. (Rapid velocity changes may take place during certain specific phenomena such as chugging; the scaling of such particular effects is considered in the bottom-up analysis. Inexact scaling of *local* phenomena such as chugging is not expected to affect overall system behavior.)

Moreover, the scaling analysis of NEDC-32288 produced three time scales, (τ^o, τ^o_{in}, and τ^o_{tr}), which scale the rates of volume fill, of inertial effects, and of pipe transfers, respectively (Section 2.4). Clearly, the systems considered here are made of large volumes connected by piping of much lesser volumetric capacity. The inertia and transit times, which are of the same order of magnitude, are much smaller than the volume fill times:

$$\tau^o >> \tau^o_{in} \approx \tau^o_{tr}$$

as shown in the NEDC-32391P tables mentioned above. It was concluded that the time scale that is controlling system behavior and therefore must be considered in scaling the system is τ^o. The other two time scales (controlled by the geometric characteristics L_I and L_V of the piping) are clearly of minor importance.

Three-Dimensional Effects

It is evident that 3D effects cannot be simulated exactly in experiments where the aspect ratio of the system is necessarily distorted (to preserve the important heights) *and* the complex SBWR volume geometries are replaced by cylindrical vessels. Mixing and stratification phenomena in the various SBWR containment volumes are discussed in Section 3.2 of NEDC-32288, where it is shown that appropriate simulation of the discharge areas of components such as vents and vacuum breakers can preserve similarity of the phenomena.

The Grashof numbers of containment volumes controlling natural circulation are considered in Section B1-2.2.2 of NEDC-32391P. For facility components that are full-height, the Grashof numbers calculated with height as the length scale match very well. Examples are shown in Tables B1-12, B1-28, and B1-47 of

numbers based on these cannot be matched, but study of 3D effects was not within the scope of these tests. The horizontal dimensions of the PANDA facility approach those of the SBWR. Moreover, representation in PANDA of the Drywell and Suppression Chamber volumes by two large vessels interconnected by very large diameter pipes essentially provides two horizontal reference lengths: for example, the diameter of one SC vessel is close to the width of the annular SBWR SC pool, while the distance between the opposing ends of the two SC vessels approaches that of the SBWR SC perimeter. Thus both length scales will be present in the PANDA model.

RAI Number 900.70

Question:

GE has identified several sources of data that may be included in the SBWR design certification database, e.g., Dodewaard startup, boron mixing tests, and CRIEPI stability tests. For all of these sources (not just those cited here), provide detailed documentation about the tests, such as facility design, scaling, and instrumentation; test specifications and test matrices; and test data and analyses. Also, document specifically how GE will use these data within the test and analysis program.

GE Response:

Section A.3.1.6 of NEDC-32391P "SBWR Test and Analysis Program Description" lists six specific sets of existing test data for which TRACG analyses are being planned. Typically, this is non NQA-1 data, much of it several years old, but that can be used to illustrate TRACG capability to correctly predict a specific parameter; PSTF containment data for as containment main vent clearing during blowdown for example. We intend to use this data to illustrate the breadth of TRACG prediction capability and to corroborate the main body of SBWR data. The specific tests included are:

1/6 Scale Boron Mixing Test
CREIPI Natural Circulation Test
Dodewaard Plant Startup
PSTF Mark III
Mark II - 4T
Suppressions Pool Stratification - Mark III

These data are from tests in SBWR-like, but not necessarily SBWR unique or scaled geometries. Since, in general, these are not SBWR unique tests, specific scaling to the SBWR configuration has not been performed, and were it to be performed, it would result in the obvious; that these are not SBWR scaled tests. We do not plan to perform any additional scaling analyses for these data sets.

Typically, the phenomena addressed are very specific, and were added to the analysis plan for additional confidence in TRACG's predictive capability. In each of the six cases identified, NEDC-32391 is very specific with regard to runs to be analyzed, and the specific purpose of each of the specific comparisons to be made.

References to specific test documentation and the specific data use are given in NEDC-32391P. The following are GE's comments on each of the six addition data sets:

1/6 Scale Boron Mixing:

This data was submitted to the NRC on the ABWR docket. The report includes scaling, facility design, test matrices, and instrumentation used.

Specific runs to be analyzed are still being defined. GE will have a detailed plan for these analyses by December 1, 1994.

CRIEPI Natural Circulation Test:

We recognize that additional information will be required by the staff . GE will prepare a data transmittal on this facility and the results to be used by December 1, 1994.

Dodewaard Plant Startup:

GE will provide the NRC staff with the test reports from the Dodewaard startup, referenced in NEDC-32391P by October 15, 1994. Reactor description and instrumentation is included in the reports. Scaling and test matrix information is not applicable in this situation.

PSTF Mark III:

The test report referenced in NEDC-32391P was submitted to the NRC as part of the GESSAR docket in 1973. Scaling (to the BWR-6 design), test facility design, instrumentation, and test matrices are included in the report.

Mark II-4T:

The test report referenced in NEDC-32391P was provided to the NRC under the Mark II Containment Program in 1976. Scaling (to several Mark II containment configurations), test facility design, instrumentation, and test matrices are included in the report.

Suppression Pool Stratification - PSTF:

The two reports referenced in NEDC-32391P were provided to the staff in 1977 and 1978 under the GESSAR docket. These reports are specifically data analysis reports from PSTF Mark III testing.

RAI Number 900.71

Question:

Explain the rationale for excluding shutdown events and beyond-design-basis events from the SBWR design certification test program. Shutdown events must be evaluated for the SBWR, and presumably will be analyzed using the same computer code(s) used for design-basis analyses. As far as beyond-design-basis accidents are concerned, the staff must determine the robustness of the passive safety systems to deal with events nominally beyond the design basis (e.g., multiple failures) and the possibility of reliance on active, non-safety systems to deal with the consequences of these events. Note: "Beyond-design-basis" in this context is not equivalent to severe accidents.

GE Response:

Beyond-design basis and shutdown events were not explicitly considered for the study that led to the definition of the Test and Analysis Program. In response to this RAI 900.71, these scenarios have been considered and GE concludes that they are covered by the defined programs.

a) Beyond-design basis events:

GE takes this set of events to mean those event and equipment failure combinations which are defined by the PRA success criteria (Attachment 19AA to the SSAR). In these events, core uncovery occurs but cladding temperature remains below 2200 F. The dominant phenomena introduced in these events (beyond the design basis events) relates to core uncovery for a period of time followed by recovery as cooling systems are restored. These phenomena are already included in the PIRT tables (e.g., C11, C13, C14, C15, C24, C25). Tests which cover these phenomena include the TLTA boiloff test, and small and large break tests in TLTA and FIST. All these tests were performed with a simulated full scale BWR fuel bundle and cladding heatup occurred over a range of temperatures and system pressures. TRACG has been qualified against these tests with excellent results (NEDE-32177P). No additional tests or analyses are needed to cover these events.

b) Shutdown events

Plant shutdown to the hot standby condition is accomplished by bypassing steam to the main condenser and through the use of the RWCU/SDC system for decay heat removal. The ICs can also be used for decay heat removal during this phase of the transient. No new phenomena are introduced in this transient, beyond those already considered. Cold shutdown is achieved through decay heat removal by the RWCU/SDC system. If these systems are not available, other core injection systems (e.g. FAPCS), can be used for decay

heat removal. One train of the RWCU/SDC system is sufficient to remove the decay heat, but two trains are engaged for the first 8 days to keep the cold leg temperature of the RCCW at 95°F. Again, no new phenomena are introduced.

RAI Number 900.72

Question:

Explain how GE can rely solely upon analysis to resolve the issues of systems interactions during the early phases of transients and accidents, when there are essentially no integral systems test data either existing or planned that cover such conditions during that time. Note that PANDA is not scaled to represent the early phase of SBWR accidents, and is incapable of representing the "worst-case" sequences for the SBWR, that is, bottom drain line and Gravity-Driven Cooling System line breaks.

GE Response:

GE is not relying solely on analysis to resolve systems interaction issues in the early phases of the LOCA transient. Figure 5.3-1 of NEDC-32391P illustrates the coverage of various portions of the transient by different integral systems tests. Section 5.3 of NEDC-32391P discusses this figure. The systems interaction analysis was performed to identify the needs for tests where systems interactions might be important, where possible adverse interactions might occur and where there could be uncertainties in the analysis. This led to the definition of the PANDA Phase 2 tests. It is true that PANDA does not have the power supply capability to simulate the decay power at 10 minutes into the transient, and that the GDCS tanks do not have sufficient capacity to simulate the full capacity in the SBWR. However, test procedures will be developed to minimize the impact of these parameters on the system transient response. This is addressed further in response to RAI 900.73. It should be recognized that the purpose of these tests is to provide representative data for code validation of the key phenomena and interactions. Thus, in the early GDCS period of the transient, the emphasis is on the interactions between the heat removal by the PCCS combined with the effects of steam condensation within the reactor and drywell. The key phenomena related to drywell depressurization, vacuum breaker opening, recycling of noncondensibles, PCCS purging and restoration of PCCS performance will all be maintained even if there are scaling distortions in some of the parameters.

Incidentally, the bottom drain line break and GDCS line break are limiting for the minimum water level in the reactor vessel. In the PANDA tests, the focus is on the containment performance and the large steam line break is the limiting break.

RAI Number 900.73

Question:

Specify as precisely as possible at what time in the accident sequence the PANDA tests that are to represent the "early" phases of main steam line breaks will begin.

GE Response:

Although the detailed procedures for the PANDA Integral Systems Tests with an early start have not been completed, it appears that these tests (M7 and M8) can simulate the SBWR containment response to a steam line break as early as 10 minutes into the transient.

At approximately 10 minutes into a main steam line break accident, the RPV pressure is calculated to have dropped to approximately 300 kPa and is nearly equal to the drywell and wetwell pressures. The PANDA vessels and connecting piping have the capability to model this transient directly from this time on except for the decay heat and the GDCS inventory addition to the RPV.

The PANDA power supply is capable of providing 1.5 MW to the electrical heaters in the RPV. The SBWR scaled decay heat at one hour after scram is approximately 1 MW. The remaining 0.5 MW is available to simulate the RPV structural stored energy for those tests beginning at one hour into the simulated SBWR accident. 1.5 MW matches the scaled SBWR decay heat at approximately 20 minutes following scram.

The PANDA GDCS was designed to provide good simulation of the PCCS condensate drain discharge geometry and discharge conditions after draining of the initial GDCS inventory to the RPV has stopped. Representation of the full GDCS capacity was not an objective for the PANDA design. As a result, the capacity of the GDCS is approximately 40% of the scaled SBWR GDCS volume.

The approach in PANDA for modeling the SBWR transients prior to one hour after scram will take advantage of the fact that a significant fraction of the SBWR decay heat during this period is used to heat the subcooled GDCS water which has drained into the RPV. By running the PANDA tests with a constant power of 1.5 MW for the period simulated prior to one hour and adjusting the initial conditions in the RPV and the GDCS, it is expected that the test start time can correspond closely to 10 minutes into the SBWR main steam line break.

As stated above, the detailed test procedures for M7 and M9, the PANDA Integral Systems Tests with an early start, have not been completed. For test M7, however, the approach described above will provide data to demonstrate the PCC capability to start-up when it is initially filled with air and RPV conditions are representative of SBWR conditions immediately following blowdown. For test M9, the RPV and GDCS conditions will be adjusted to cause vacuum

breaker opening and reintroduction of air to the drywell and PCC. Test M9, therefore, will demonstrate the PCC startup capability if air is reintroduced to the drywell via the vacuum breakers early in the transient.

RAI Number 900.74

Question:

PANDA tests will be initiated "on the run", therefore, a transient condition will be established which is intended to simulate a particular reactor transient. How will this be accomplished without significantly affecting the transient under study?

GE Response:

The initial conditions for the PANDA tests will be based on calculated conditions in the SBWR at the time in the transient corresponding to the test start time. For the transients to be simulated, the SBWR pressures, temperatures, liquid levels, and non-condensible gas concentrations which will be the basis for the PANDA initial conditions are not varying rapidly with time. Therefore, establishing initial conditions based on the calculated values for these slowly varying parameters will not affect the test transient.

RAI Number 900.75

Question:

The staff has previously requested detailed test matrices for the PANTHERS Isolation Condenser (IC) tests. These have never been provided and the information in Appendix A of NEDC-32391P, "SBWR Test and Analysis Program Description," is not sufficiently detailed (e.g., noncondensable gas concentrations, test duration, test cycles, etc.). Provide this information for review. In addition, address the concerns raised about instrumentation for PANTHERS PCCS testing (Q900.68 above) for the IC tests.

GE Response:

The PANTHERS Test Requirements and Test Specification were sent to NRC in MFN 119-92, dated May 27, 1992. Rev. 2 of this specification was transmitted by MFN 101-94, dated August 31, 1994.

RAI Number 900.76

Question:

The scaling analysis submitted with NEDC-32391P, "SBWR Test and Analysis Program Description," is an improvement over previous documentation provided by GE; however, additional work is required to demonstrate that for each of the important phenomena identified in the phenomena identification and ranking table (PIRT), the range of thermal-hydraulic conditions expected in the SBWR is covered by one or more tests in the test program.

GE Response:

Data has or will be obtained for all of the phenomena marked 'High' in the phenomena identification and ranking table (PIRT). The data comes from a combination of testing programs and plant data. The type of data used for each phenomena is indicated by the test coverage matrix shown in Figures 5.5-1 and 5.5-2 of the TAPD. Table 1 of this RAI includes the information in those tables along with scaling information on the phenomena. More detailed information showing specifically which test or tests are used to obtain data for each phenomena is also contained in the tables in chapter 5.

Data for some of the parameters have been obtained from operating BWR's. Therefore the data will be over the same ranges as expected in the SBWR. Additionally, data from BWR simulator facilities such as SSTF, TLTA, FIST, PSTF and the Boron Mixing Facility have been used. These facilities were design to simulate operating BWR behavior for accidents and transients which are very similar to those for the SBWR. A description of each of these facilities is included The TRACG Qualification document, NEDE-32177P, Rev 1. Data obtained from this category is marked in the "BWR facility" column of Table 1.

In addition, for those parameters that were considered to be particularly important, a detailed review of the test data and ranges used for coverage was performed. This information is contained in the Qualification Data Base (QDB) that supports the TAPD. Table 1 indicates which PIRT phenomena are reviewed in the QDB. Phenomena that is covered by data from GIST, GIRAFFE, PANDA or PANTHERS has already been scaled in Appendix B of the TAPD. These phenomena are indicated by checks in the "Scaled in App. B" column of Table 1.

Table 1. PIRT phenomena data coverage

PIRT #	Phenomena	Issue	Test Coverage				Scaling		
			Separate Effects Tests	Component Tests	Integral System Tests	Plant Data	Scaled in QDB ?	Scaled in App B ?	Data from BWR Facility ?
A1	LP flashing/redistribution		X	X	X			X	X
A2	LP heat slab stored energy		X	X	X		X	X	X
A3	Inlet orifice uncovery			X	X				X
A4	LP void fraction		X	X	X			X	X
A5	LP void collapse/inlet subc.		X	X	X			X	X
A9	LP stratification		X	X	X			X	X
B1	Bypass flashing		X	X	X			X	X
B2	Bypass level		X	X	X				X
B4	CCFL at bottom of bypass			X	X				X
B5	CCFL at top of bypass			X	X				X
B6	Channel to bypass leakage			X	X	X		X	X
B7	Bypass refill			X	X			X	X
C1AX	Void coefficient					X			
C1BX	Doppler coefficient					X			
C1CX	Scram reactivity					X			
C2AX	Interfacial shear and h.t.		X	X	X	X		X	X
C2BX	Subcooled boiling		X		X	X		X	X
C3AX	Fuel pellet power dist.		X			X			
C3CX	Fuel gap conductance		X			X			
C4	Core flashing		X	X	X			X	X
C5	Inlet orifice uncovery			X	X				X
C6	Inlet orifice CCFL			X	X				X
C7	Upper tieplate CCFL		X	X	X				X
C8	Multibundle flow dist.			X	X	X			X
C8X	Core void collapse			X	X	X			
C10	Core void distribution		X		X	X		X	X
C11	Channel to bypass leakage			X	X	X		X	X
C12	Natural circulation flow		X		X	X		X	X
C13	Dryout/boiling transition		X		X				X
C14	Film boiling (low flow)		X		X				X

Table 1. PIRT phenomena data coverage (cont'd)

			Test Coverage				Scaling		
PIRT #	Phenomena	Issue	Separate Effects Tests	Component Tests	Integral System Tests	Plant Data	Scaled in QDB ?	Scaled in App B ?	Data from BWR Facility ?
C15	Film boiling (disp. drop.)		X		X				X
C23	Core pressure drop		X	X	X	X		X	X
C24	Decay heat				X	X		X	X
C25	Fuel stored energy				X	X		X	X
C26	Critical power for 9 ft core		X				X		
D1	GT flashing		X	X	X			X	X
D2	CCFL at top of GT			X	X				X
D4	Refill of GT			X	X				X
E1	D C break uncovery			X	X		X		X
E2	D C void profile		X		X			X	X
E3	GDCS interaction				X			X	
E5	D C heat slabs			X	X	X		X	X
E6	D C flashing		X		X				X
E7	IC interaction								
E8	D C break flow		X		X			X	X
F1	Chimney void distribution		X	X					X
F2	Chimney flow distribution			X	X				X
F4	Mixing at top of chimney			X		X			
F5	Geysering during startup				X	X			
I1	Separator CU/CO			X		X			
I2	Separator inertia					X			
I3	Separator pressure drop			X		X			
L1X	Steamline pressure drop				X	X			
L2X	Steamline acoustic effects				X	X			
L1	SRV/DPV critical flow		X		X		X	X	X
L2	Droplet entrainment		X		X		X		X
L3	Transition to unchoked flow		X		X		X		X
L5	Multiple choked locations				X			X	
Q1	IC pressure drop			X			X	X	

Table 1. PIRT phenomena data coverage (cont'd)

PIRT #	Phenomena	Issue	Test Coverage				Scaling		
			Separate Effects Tests	Component Tests	Integral System Tests	Plant Data	Scaled in QDB ?	Scaled in App B ?	Data from BWR Facility ?
Q2	IC capacity			X			X	X	
Q3	Stratification in IC drums			X			X	X	
Q4	IC pool stratification			X			X	X	
Q5	Secondary side heat transfer			X			X	X	
ST1	Hydrodynamic stability		X						X
ST2	Corewide stability					X	X		
ST3	Regional stability					X	X		
ATW1	Boron mixing in bypass			X					X
ATW2	Boron stratification to LP				X				X
ATW3	Boron delivery to core				X				X
XL1	Interaction between multiple IC modules and units			X	X				
XL3	System interaction – GDCS/System depressurization				X			X	
CONTAINMENT									
BR1	Break mass flow	Critical flow	X	X	X		X		X
		Friction	X	X	X		X		X
		Entrainment	X	X	X		X		X
MV1	Main vent flow				X		X		X
MV3	Vent clearing time				X		X		X
SQ1	SRV flow		X		X			X	X
DW1	Flashing/evaporation in DW				X			X	
DW2	Condensation on DW walls				X		X	X	X
	Degredation of conduction				X		X	X	X
	Wall/Structure conduction				X		X	X	X
DW3	3-D effects	Phase distribution			X		X	X	
		Noncondensables distribution			X		X	X	
		Buoyancy/ natural circulation			X		X	X	

Table 1. PIRT phenomena data coverage (cont'd)

			Test Coverage				Scaling		
PIRT #	Phenomena	Issue	Separate Effects Tests	Component Tests	Integral System Tests	Plant Data	Scaled in QDB ?	Scaled in App B ?	Data from BWR Facility ?
DW4	Condensation on reactor outflows	Interfacial Heat Transfer			X		X	X	
		Degradation by N/C			X		X	X	
WW1	Condensation/evaporation of main vent discharge	Interfacial Heat Transfer		X	X		X		X
		Degradation by N/C					X		X
WW2	Condensation/evaporation of SRV discharge	Interfacial Heat Transfer		X	X				
WW3	Condensation/evaporation of PCC vent discharge	Interfacial Heat Transfer		X	X		X	X	
WW4	Free surface condensation/ evaporation	Interfacial Heat Transfer			X			X	
		Degradation by N/C			X		X	X	
WW5	Heat sources/sinks	Condensation on WW walls			X		X	X	X
		Conduction through WW walls			X		X	X	X
		Degradation by N/C			X		X	X	X
WW6	Pool mixing and stratification	Bouyancy/ natural circulation		X	X		X	X	X
WW7	3-D effects in gas space	Temperature distribution			X		X	X	
		noncondensable distribution			X		X	X	
		Interfacial shear					X	X	

Table 1. PIRT phenomena data coverage (cont'd)

PIRT #	Phenomena	Issue	Test Coverage: Separate Effects Tests	Test Coverage: Component Tests	Test Coverage: Integral System Tests	Test Coverage: Plant Data	Scaling: Scaled in QDB ?	Scaling: Scaled in App B ?	Scaling: Data from BWR Facility ?
		Mixing, entrainment into jets					X	X	
		Bouyancy/natural circulation					X	X	
		Phase separation					X	X	
WW8	Containment spray condensation	Interfacial Heat Transfer		X	X			X	
		Degredation by N/C			X			X	
WW9	Containment hydrodynamic loads	Pool Swell		X	X		X		
		Condensation oscillation			X		X		
		Chugging			X		X		
		SRV Discharge			X		X		
GD2	GDCS flow				X		X	X	
PC1	PCC flow/pressure drop			X	X		X	X	
PC2	Condensation on primary side	Interfacial H.T.	X	X	X		X	X	
		Degradation by n/c	X	X	X		X	X	
		Shear Enhancement						X	
PC3	Secondary side heat transfer	Pool temp. dist.		X	X		X	X	
		Pool void dist.		X	X		X	X	
		Natural circulation		X	X		X	X	

Table 1. PIRT phenomena data coverage (cont'd)

			Test Coverage				Scaling		
PIRT #	Phenomena	Issue	Separate Effects Tests	Component Tests	Integral System Tests	Plant Data	Scaled in QDB ?	Scaled in App B ?	Data from BWR Facility ?
		Secondary side entrainment		X	X		X	X	
PC4	Parallel PCC tube effects	Friction		X	X		X	X	
		Void fraction		X	X		X	X	
PC5	Parallel PCC unit effects	Friction		X	X		X	X	
		Void fraction		X	X		X	X	
PC6	PCC fan component separation						X		
PC8	PCCS startup with n/c	Purging by presssure diff.			X		X	X	
		Degredation by N/C			X		X	X	
DWB1	Leakage between drywell and wetwell			X	X		X	X	
VB1	Vacuum breaker flow characteristics			X			X		
EQ1	Equalization line flow				X			X	
EQ2	Equalization line sloshing				X			X	
OC1	Heat transfer to safety envelope								
DPV1	Mass flow in DPVs	Critical flow					X		
		Friction					X		
		Entrainment					X		
CW1	Containment liner gap conductance								
CW2	Concrete properties at high temperature			X			X		

Table 1. PIRT phenomena data coverage (cont'd)

			Test Coverage				Scaling		
PIRT #	Phenomena	Issue	Separate Effects Tests	Component Tests	Integral System Tests	Plant Data	Scaled in QDB ?	Scaled in App B ?	Data from BWR Facility ?
PAR1	Passive Autolitic Recombiners	Operation in hydrogen rich environment		X			X		
PAR2		Added heat load from recombination reaction							
XC1	System interaction	IC/DPV/PCCS			X			X	
XC2	System interaction	IC/DPV/ GDCS/PCCS			X			X	
XC4	System interaction	FAPCS/ PCCS			X			X	
XC5	System interaction	multiple PCC modules and units			X			X	
XC6	System interaction	light noncondensable DW/PCCs/WW			X			X	
XC7	System interaction	containment system response (DW/WW/MV)				X			X

RAI Number 900.77

Question:

Responses to the staff's previous requests for additional information (April 11, 1994) are also needed to determine the adequacy of NEDC-32391P, "SBWR Test and Analysis Program Description." Of particular interest are responses to Q901.23 through Q901.27.

GE Response:

Responses to the referenced RAIs have been sent in to the NRC by letter MFN 096-94, *SUBMITTAL OF ADDITIONAL INFORMATION ON LICENSING TOPICAL REPORT* (NEDE-32177P and NEDE-32178P), dated September 20, 1994.

RAI Number 900.78

Question:

The SBWR is unique from the standpoint of suppression pool thermal capacity. It is designed only for the first hour of decay heat energy, unlike previous designs which could accommodate all of the decay heat energy. Therefore, discuss the interactions expected between the PCCS and the suppression pool during transient periods such as PCCS purging, return to steady state operation, and vacuum breaker opening. Specifically, discuss the potential of opening the main vents for short periods, thereby sending mass and energy to the pool and possible instabilities as seen in the single tube condensation tests at the University of California (Berkeley). This discussion should rely on test data as much as possible.

GE Response:

The statement in this RAI that the SBWR design is unique from the standpoint of suppression pool thermal capacity is incorrect. All BWR pressure suppression pools are sized to accommodate the primary system blowdown energy. None of the suppression pools in existing GE pressure suppression containment types are designed to accommodate all of the decay energy without resort to some other energy removal system. In the absence of such a system, the pool will continue to heat with time as decay energy is added.

In earlier containment designs, the suppression pool temperature is limited by operation of the pool cooling mode of the Residual Heat Removal (RHR) System. The suppression pool absorbs the blowdown energy prior to operator initiation of RHR. Energy addition to the suppression pool continues by flow of drywell steam (generated by decay heat) through the main vents, and energy is removed from the pool by the RHR system to the ultimate heat sink. The peak pool temperature is established by the relative rates of energy addition and extraction. Typically, a maximum pool temperature near 190 degrees F occurs about 6 hours into the accident scenario, when the RHR heat exchanger delta T is sufficient to remove energy at the rate of energy addition to the pool from decay heat. The suppression pool temperature then slowly decreases as the decay energy addition decreases.

In the SBWR the situation is similar. During the blowdown period, the suppression pool absorbs the majority of the primary system energy, although there is some energy extraction by the PCCS. Depending on the break scenario, the blowdown period lasts from about 10 to 30 minutes. Following blowdown, GDCS reflood of the vessel causes subcooling of its fluid contents, and little steaming occurs until about 1 hour into the accident scenario. At this time, the PCCS is capable of rejecting all of the decay heat. In this way, the PCCS is analogous to the RHR system.

A critical element of SBWR design is the PCCS heat exchanger vent configuration. The PCCS vent exits into the suppression pool at a shallower submergence than the top main vent. This geometry is important, because the SBWR pressure suppression containment, like all earlier containments, is a forced flow, pressure driven system, not a temperature driven natural convection system. In all pressure suppression containment systems, mass and energy are added to the drywell from the break in the primary system, and the drywell pressure increases. The pressure will continue to increase, lowering the water level in the vent system, until a flow path is established between the drywell and the wetwell. The wetwell pressure is set by the thermodynamic conditions in the wetwell, including partial pressure of the original wetwell air (or nitrogen in the case of the SBWR), the partial pressure of the air purged over from the drywell to the wetwell air apace, and the vapor pressure of steam corresponding to the suppression pool surface temperature. Once the vents have cleared, the drywell pressure is equal to the wetwell pressure, plus the submergence head of the vents, plus any flow head losses in the vent system. There would be flow from the drywell to the wetwell even if there are only non-condensable gases in the drywell. (In fact, some of the containment testing performed in the 1970's and '80's was performed with only non-condensables.) Once sufficient mass and energy are added to the drywell so that the vent submergence head is overcome, flow will occur. This holds true whether the flow is through the main vents, or through the PCCS heat exchangers

Early in the LOCA scenario, mass and energy addition rates into the drywell from the primary system are larger than the heat removal capacity of the PCCS. During blowdown, the drywell pressure is such that both the PCCS vent and the main vents are cleared, and flow goes to the suppression pool via both paths. As primary system steaming decreases, the drywell pressure will decrease, eventually allowing the top main vents to re-flood and flow to the suppression pool will stop. Flow will still occur, however, through the PCC heat exchanger and PCC vent. It is the difference in submergence between the main vents and PCCS vent that preferentially directs flow through the heat exchanger, and shifts the primary LOCA heat sink from the suppression pool to the PCCS pool.

Table 1 illustrates both the similarities and differences in suppression pool design as containment configurations have evolved. This table gives the ratio of pool volume to core rated thermal power. Both blowdown energy and decay heat are a direct function of core rated power. Thus the ratio of pool volume to core thermal power is a direct indication of the suppression pool's ability to absorb the total primary system accident energy. The value given for the SBWR is the highest of all the containment types listed. The design is very robust. The relatively high value of this parameter for the SBWR is the result of two factors, (1) the potential for thermal stratification in the SBWR suppression pool, which has no safety grade system capable of mixing the pool, and (2) the requirement that the pool absorb both the blowdown energy and that small fraction of the excess decay energy that is released, until the PCCS system is capable of assuming the full load at about one hour.

Table 1
Ratio of Suppression Pool Volume to Core Thermal Power

Containment Type	Ratio (Cubic Feet per MWth)
SBWR	57.58
ABWR	32.20
Mk III (GESSAR)	36.21
Mk III (Grand Gulf)	35.48
Mk II (Nine Mile Point 2)	46.58
Mk I (Browns Ferry)	37.35

In the SBWR, reopening of the main vents is not expected to occur following GDCS reflood of the RPV. If, due to the addition of non-condensables, for example, the PCCS heat rejection capability temporarily drops below the decay energy level, the drywell pressure will increase. However, before the drywell pressure reaches the point where the main vents will reopen, a pressure difference will exist that will clear the PCCS vent, effectively purging the non-condensables and re-establishing PCCS performance.

Even if it is postulated that flow through the main vents is somehow reestablished, the amount of energy added to the pool before an effective PCCS purge of non-condensables causes only a small increase in suppression pool temperature. A bounding calculation of an event of this type was transmitted to the NRC staff by MFN No. 214-93. This calculation was based on the bounding assumption that all the decay heat energy is absorbed by the suppression pool during the time period required to purge all the hydrogen produced by a 100% metal-water reaction from the drywell to the wetwell via the PCCS. The resulting additional pool heatup for this scenario is 3 degrees K.

At one hour into the accident scenario, the steam generated by decay heat in the SBWR is about 12 kg/sec.. The top vent area of the SBWR is 3 square meters, yielding a mass flux of about 4 kg/m^2-sec. The condensation regime has been observed to change from steady to intermittent (chugging) at mass fluxes lower than 10 lbm/sec ft^2 (48.9 kg/sec m^2). Therefore, even if main vent flow were to reoccur, it would be within the chugging regime. Cyclic flooding and re-clearing of the main vents that occurs during chugging results in improved suppression pool mixing, and a reduction of pool thermal stratification. The SBWR design uses conservative assumptions for suppression pool stratification, based on limited mixing. While the effect of chugging in reducing thermal stratification is difficult to quantify, it is certainly present, and the effect of the energy addition to the pool would likely be less than the 3 degrees K estimated above.

Instabilities were seen in the first single tube condensation experiments performed at UC Berkeley. This experiment, reported in NEDC-32310, "Single

Tube Condensation Test Program", was performed in a natural circulation loop. Subsequent single tube experiments utilizing forced circulation loops, including two experiments at UC Berkeley and two at the Massachusetts Institute of Technology, have not shown any evidence of flow oscillations or instabilities. Thermocouple instrumentation of the heat exchanger tubes in the PANTHERS experiment (see response to RAI 900.68) make it possible to monitor for instabilities in this prototype heat exchanger test. No evidence of instabilities has been identified in data reviewed to date, which include conditions that span the PCCS flow regime. Given that the SBWR is a forced flow design, and that no instabilities have been seen in forced flow experiments, they are not expected to be a factor in SBWR performance. Also the condensation instabilities seen in the UC Berkeley natural convection experiments were local in nature, and did not greatly effect the overall heat rejection within the tube.

RAI Number 900.79

Question:

Heat loss has proven to be a significant problem in evaluating the GIRAFFE data. Therefore, provide the heat loss evaluation of both the PANTHERS and PANDA facilities and discuss how these losses will be considered in the evaluation of the test data.

GE Response:

Reference: PANTHERS-PCC TEST PLAN AND PROCEDURES, SIET Document No. 00098PP91, Revision 1, July 12, 1994, sent to the NRC in MFN No. 098.94, dated August 16, 1994.

Section 8.1.2.5 of the PANTHERS Test Plan & Procedures (see reference) gives the equation for the global energy balance of the PCC at PANTHERS. The equation includes the heat losses of the inlet and outlet lines. However, these heat losses were measured during the shakedown of the test facility and found to be negligible (i.e., less than 50 kW) compared to the total thermal power (around 1 to 14 MW). Therefore, the condensation thermal power formula will be simplified to that shown at the end of the referenced section.

Quantification of heat losses for PANDA is a planned item in the test facility startup program. The measurements have not yet been performed. PANDA is very heavily insulated, and heat losses are not expected to have a major effect on the results. The design goal is to limit heat losses to 10% of the decay heat at 24 hours into the LOCA scenario. Calculations indicate losses will be substantially less than the target values.

RAI Number 900.80

Question:

Interaction between the ICs and the PCCS may have a profound impact on the performance of the system. Discuss the possibilities of tests considering both units operational. In particular, the early in time test to obtain GIST-type data should be one of the tests considered.

GE Response:

The systems interaction studies performed as part of the SBWR test reassessment and reported in NEDC-32391P indicated that the minimum RPV water level was slightly effected by the presence of the IC and PCC for some postulated break scenarios. However, there was essentially no effect on system performance. The SBWR is a very robust design from the standpoint of core cooling. Minimum accident water levels are calculated to be approximately 1 to 4 meters above the top of the fuel, and peak clad temperatures are essentially unchanged from steady state performance values. Overall system performance would only be effected if the water level dropped below the top of the fuel, and even then there would be very significant margins to 10CFR50.46 and Appendix K temperature limits.

Appendix A of NEDC-32391 defines the tests GE has concluded are technically adequate for SBWR certification. PANDA test M6 was added to the matrix specifically to address IC effects. As a result of staff comments from the meeting on August 18, we are considering adding IC operation to PANDA tests M8 and M9 as well. As noted in the response to RAI 900.73, PANDA tests M7 and M9 will be started approximately 10 minutes into the accident scenario.

RAI Number 900.81

Question:

Transient behavior is of particular concern to the staff, therefore, each PANDA test duration should include at least one purge cycle of the PCCS. Confirm if that is the case.

GE Response:

It is unclear what is meant by a "purge cycle" in this RAI statement. Every PANDA test begins with some air fraction within the drywel. Over time, this air fraction will decline, but there will always be some small residual air content in the drywell. Tests M1 through M4, are of this type. Tests M5 through M9 have test conditions defined to address specific TRACG qualification needs as defined in NEDC-32391P. Some, but not all, of these tests will result in the vacuum breaker opening, and re-enty of non-condensables into the drywell. In these cases, the purge of these non-condensables into the wetwell will be investigated. Again, there can be no assurance that all the air will be purged from the drywell in any given test.

Superimposed on these system purges may be short cycle variations in the non-condensable content with the PCC heat exchanger. These will be investigated, should they occur.

If the staff will be more specific in what they mean by "PCCS purge cycle" we can respond more fully.

Purdue University Questions - Set 5

1. Provide the SBWR drywell spray flow rate and water temperature.

2. Provide the SBWR wetwell spray flow rate and water temperature.

3. What were the droplet size, flow rate, and water temperature of drywell and wetwell sprays that were assumed in TRACG analyses?

GE Response:

1. The maximum allowable differential pressure across the containment liner determines the drywell depressurization rate and consequently the maximum allowed drywell spray flowrate. These parameters have not been finalized yet.

   The Fuel & Auxiliary Pools Cooling System (FAPCS) pumps are variable speed pumps and can provide a flow rate between 257 and 422 m^3/h in the drywell spray mode. If these flow rates are too high, it can be reduced to 150 m^3/h for long term operation without causing problems with the pump. If an even lower flow rate is required, the flow can be partly bypassed by opening the valve in the discharge line to the suppression pool.

   The spray temperature has been calculated to be 55^{o}C with a spray flowrate of 346 m^3/h with the supression pool water (source of drywell spray water being cooled by the FAPCS heat exchanger) at 79^{o}C.

2. The maximum allowed wetwell spray flowrate has not been finalized yet.

   The Fuel & Auxiliary Pools Cooling System (FAPCS) pumps are variable speed pumps and can provide a flow rate between 307 and 445 m^3/h in the wetwell spray mode. If these flow rates are too high, it can be reduced to 150 m^3/h for long term operation without causing problems with the pump. If an even lower flow rate is required, the flow can be partly bypassed by opening the valve in the discharge line to the suppression pool.

   The spray temperature has been calculated to be 55^{o}C with a spray flowrate of 346 m^3/h with the supression pool water (source of wetwell spray water being cooled by the FAPCS heat exchanger) at 79^{o}C.

3. The drywell and wetwell sprays are simulated with the use of a TRACG PUMP component and a component representing the system heat exchanger. The flow rates used for the two spray modes were 321 m^3/hr and 307 m^3/hr for the drywell and wetwell, respectively. The temperature of the spray is not prescribed. The water is circulated through the simulated heat exchanger, characterized by a heat transfer area of 386 m^2, an overall heat transfer coefficient of 1510 Wm^2-K, and a sink temperature of 313K. It is expected that the outlet temperature will be only slightly above the sink temperature. Spray droplet size is not prescribed. It is determined by TRACG as the value implied by a critical Weber number of 6.5, based on relative velocity, or 0.2 mm, whichever is larger. As an example, for containment conditions of 300 kPa and 100% steam, the relative velocity is about 5 m/sec, yielding a droplet size in the range of 7 to 8 mm.

RAI Number: 900.83

Question:

Discuss how TRACG models mixtures of steam and non-condensable gases, including mixtures with more than one species of non-condensable gas (e.g., steam, nitrogen, hydrogen).

GE Response:

In addition to steam, TRACG solves the mass conservation equation for a second gas species. In a given computational cell, the two vapor species are perfectly mixed so that they have the same temperature and velocity. Thus the noncondensible gas is transported with the steam to the next cell with the same velocity as the steam. The concentration and partial pressure of the noncondensibles are tracked in every cell. Conventional donor cell techniques are used to calculate the flow of the noncondensibles from one cell to the next. The assumption of perfect mixing within a cell can make the results sensitive to the cell size, and the cell size must be chosen appropriately for the problem being solved. In a three (or two) dimensional grid, buoyancy effects due to larger concentrations of a light gas in certain regions can be properly accounted for within these assumptions.

Currently, TRACG allows for only one gas field other than steam. A mixture of two species would be treated as a gas with averaged properties. For this specific analysis of the containment design basis (100% metal-water reaction) event, a mass conservation model for a second gas field is being implemented in TRACG.

RAI Number: 900.87

Question:

Provide details of the CSAU study related to SBWR containment analysis.

GE Response:

GE intends to follow the CSAU methodology developed by Boyack et al (Quantifying Reactor Safety Margins, NUREG/CR-5249, 12/89). The 14 step methodology developed by this team is outlined in the attached figure from the above reference. Currently, GE is at Step 8 in the process. The test and analysis needs have been defined and the Separate Effects Data analysis is completed. The remaining steps involve the determination of bias and uncertainty in the TRACG calculations (Step 9), establishing whether there is a scale effect (Step 10), and accounting for the effects of uncertainties in the plant operating parameters (Step 11). Under Step 9, all the parameters identified as High in the PIRT tables (e.g., 4.1-2(a)) will be addressed. It is expected that a much smaller subset of this list will show significant effect on the containment pressure and temperature response in the preliminary sensitivity studies. For this reduced set of sensitive parameters, reasonable ranges will be defined for the subsequent statistical analysis in Steps 12 and 13. The model and plant parameters will be perturbed from their nominal values in a set of TRACG calculations. These calculations will serve to define the upper 95th percentile pressure and temperatures, which will be compared with the allowable design limits.

RAI Number: 900.91

Question:

The staff is concerned that assumptions termed as "licensing basis" which are used for calculations of accidents and transients in the SBWR do not represent the actual operation of the plant which would be expected in such cases. These analyses routinely exclude operation of safety systems that would be expected to operate, such as the isolation condenser. It is also possible that selected non-safety systems could operate and change the integral plant behavior. GE should include in its test programs a range of test conditions to ensure that the data will represent a sufficiently broad basis for code assessment assuming both "licensing basis" conditions and realistic plant conditions during accidents.

GE Response:

The "licensing basis" calculations do not take credit for equipment not classified as Engineering Safeguards. Also, single failure assumptions are required in the analysis. However, GE has performed analysis to show that scenarios where such equipment is available improve the accident response, and that the licensing assumptions do in fact provide bounding results.
In NEDC-32391P, calculations have been performed with the ICs available. Cases have also been run with active systems operating (CRD and FAPCS). Based on these calculations (Appendix C), testing needs have been defined. The PANDA tests will include tests where the ICs are operational. The effects of the FAPCS in the drywell spray mode will be simulated by adding cold water to the drywell. The GIST tests included one (A05) in which the CRD system was simulated. The ICs have a beneficial effect on the limiting LOCA transients and were not simulated in GIST.

RAI Number: 900.93

Question:

Provide a discussion of vacuum breaker actions for analyzed transients and accidents, including a Gravity-Driven Cooling System line break and include discussion of assumptions made for both expected and "licensing-basis" scenarios. In addition, detail why failure to close (after actuation) of a drywell-to-wetwell vacuum breaker is not, in GE's view, a credible failure.

GE Response:

Vacuum breaker cycling has been predicted for nearly all LOCAs, following GDCS initiation. The injection of subcooled GDCS water into the vessel reduces the pressure in the vessel and drywell to below the setpoint of the vacuum breakers and they cycle open, returning noncondensible gases to the drywell. Predictions indicate the vacuum breakers remain open for only brief periods, and can cycle several times during the GDCS injection period of the transient. The LOCA transient which is predicted to provide the most vacuum breaker cycles is the GDCS line break. This accident dumps the inventory of one GDCS pool directly into the drywell, which produces vacuum breaker openings. Later, as the GDCS flow from the unbroken lines fills the vessel to the level of the break and spills over into the drywell, additional vacuum breaker openings are predicted. Predictions of this transient indicate that as soon as the decay heat boiloff resumes, the drywell is re-pressurized, flow through the PCCS resumes and the noncondensibles are slowly purged through the PCCS, back to the wetwell.

Differences in the 'licensing basis' and expected LOCA calculations such as those presented to the NRC relate to availability of additional safety systems. As was shown, the use of intermittent drywell spray, while reducing the drywell pressure, also produces additional vacuum breaker cycling. For all cases analyzed to date however, the PCCS was able to return the recycled noncondensibles to the drywell and retain part of the pressure reduction benefit resulting from the use of the spray.

The assumption of the reliability of vacuum breaker operation is based on the design requirement of the vacuum breaker. The vacuum breaker valve design reliability objective is to fail to open or close less than once in every ten thousand demands. To achieve this objective, simplicity of design was used. The design configuration selected is a vertical poppet valve opening with high wetwell pressure and closing by gravity plus drywell pressure. The valve has double sealing surfaces one hard and one soft. The sealing surfaces are designed so that a design basis seal obstruction could be accommodated on one seal without the failure of the second seal. To demonstrate reliability, the prototype valve has undergone extensive testing. Before the valve reliability test was begun, the valve was aged and degraded to simulate sixty years of service. Aging consisted of soft seal irradiation, whole valve thermal aging, whole valve

dynamic aging, design basis accident steam aging and ingestion of grit to coat seal and moving surfaces. The valve was then cycled three thousand times without failure. Using a Bayesian statistical approach, three thousand cycles without failure was shown to demonstrate a high probability of meeting the reliability objective of one failure in ten thousand.

RAI Number: 900.94

Question:

Provide a listing of the TRACG code version used for each TRACG run analyzed and presented during the "scaling" part of the August 18, 1994, meeting, including a discussion of any differences in the results obtained with the "preliminary" and the "Level 2 " versions of the TRACG code.

GE Response:

The results discussed at the meeting are contained in Figures B.3-1 to B.3-4 for GIST and Figures B.3-5 to B.3-6 for GIRAFFE. For GIST, TRACG calculations are shown for the test, for the current SBWR design and the 1988 SBWR design. Of these, the test predictions and the calculations for the current SBWR design were made with the Level 2 version of the code, while the calculations for the 1988 SBWR design were old calculations. Calculations made with the preliminary code version and the Level 2 version have shown very little differences for other similar calculations. The GIRAFFE test predictions as well as the corresponding calculations for the SBWR in Figures B. 3-5 and B.3-6 were all made with the Level 2 version of the code.