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Central File

March 7, 1994

Docket No. 52-004

Mr. Patrick W. Marriott, Manager
Licensing & Consulting Services
GE Nuclear Energy
175 Curtner Avenue
San Jose, California 95125

Dear Mr. Marriott:

SUBJECT: SIMPLIFIED BOILING WATER REACTOR (SBWR) TESTING PROGRAM

The purpose of this letter is to inform you of the Nuclear Regulatory Commission (NRC) staff's positions concerning several issues that have arisen in its review of the SBWR test program. These issues have been discussed with GE Nuclear Energy (GE) during previous meetings related to the SBWR test program. The issues involve:

- Acceptability of the Gravity-Driven Cooling System (GDCS) Integral Systems Test (GIST) program data as the sole integral experimental basis for demonstrating the performance of the passive safety injection system of the SBWR and for validating the TRACG modeling of that system's behavior.
- The requirement for additional test data from the PANDA facility.
- The requirement for data concerning the performance of the isolation condenser (IC).
- The requirement for test data demonstrating the performance of the passive containment cooling system (PCCS) in the presence of lighter-than-air noncondensible gases.
- Availability of GIRAFFE experimental and facility data and other experiments run on behalf of GE.

A brief presentation of the staff's position on each issue is provided below (with more detail on several of the issues provided in the enclosure). Following this information are discussions on testing program requirements of 10 CFR 52.47 and the impact of the staff's test program concerns on the SBWR review schedule.

<u>Acceptability of the GIST Program Data</u>

In MFN No. 235-93 dated December 16, 1993, GE submitted a document entitled, "Response to NRC Findings on GIST," in response to NRC's request to provide a justification for the adequacy of the GIST program as an integral systems test

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to support design certification for the SBWR. The staff has reviewed this document and finds that it does not justify acceptance of the GIST data as the sole experimental basis for demonstrating the performance of the passive safety system of the SBWR nor for validating the TRACG modeling of that system's behavior. The principal reason for this conclusion is that there are significant differences between the GIST facility and the current version of the SBWR, including failure to include components or systems that could interact with the passive safety systems and insufficient characterization of facility thermal-hydraulic behavior. As a consequence, it is the staff's view that a properly scaled and configured integral systems test is essential to support design certification of the SBWR. This requirement could be met either by testing of a modified existing facility or of a newly constructed one; the staff is available to comment on any proposal that GE cares to offer.

In this connection, it should be pointed out that GE's approach has been to perform tests involving important phenomena identified through the phenomena identification and ranking table (PIRT) process, and to show that these phenomena are modeled by TRACG. The staff does not agree that this approach is sufficient to validate the code for situations involving complex behavior of several interactive multi-component systems, in particular, those that are operative during operation of the GDCS. As discussed during our meeting with you on February 8, 1994, this is apparently the basis of our misunderstanding concerning the application of the GIST as an integral test facility.

Requirement for Test Data from PANDA

PANDA is the only large scale (1:25), full-height facility simulating the reactor vessel, wetwell, drywell, GDCS pool, and IC and PCCS pools and heat exchangers. It is meant to test selected components in an integral configuration, primarily to study multi-dimensional behavior under long-term post-accident conditions at low pressure. Since the scale of this facility is so much larger than GIST (1:508) and GIRAFFE (1:400), and since PANDA is the only one of these facilities to adequately represent the current design of the passive heat removal and emergency core cooling (ECC) systems, the staff maintains its position that the PANDA tests are necessary to fulfill the requirements of 10 CFR 52.47 for analytical model verification and proof of system performance. This is contrary to the original GE position that PANDA tests are to be confirmatory, and to the more recent offer of two main steam line break tests as "all the testing necessary for design certification" (GE response to staff request for additional information SRXB.39). Once again, we inform you that tests in the PANDA facility are required for design certification. Furthermore, we repeat our request for details of the full PANDA test program and for a scaling analysis of this facility so that we may reach agreement on the test matrix needed to cover our concerns. In your response, we suggest that you consider the above finding concerning GIST.

Requirement for Data on the Performance of the IC

The staff stated in SECY-92-339, "Evaluation of the General Electric Company's Test Program to Support Design Certification for the Simplified Boiling Water Reactor," dated October 6, 1992, that IC tests in the PANTHERS facility are required for design certification. In your response (MFN No. 219-93) of November 30, 1993, you reach the opposite conclusion. For the reason that the IC system is the only safety system capable of removing decay heat at full pressure, and other reasons stated in the enclosure, the staff maintains its original position. To proceed with its review, the staff needs details of the facility design, test specifications, and the test matrix. Alternatively, you may prefer to remove the credit for the IC system taken in Chapter 15 of the SBWR standard safety analysis report, as discussed in the enclosure.

Performance of the PCCS in the Presence of Lighter-Than-Air Noncondensible Gases

GE has not demonstrated that hydrogen generation during an accident will not adversely affect the operation of the PCCS. The staff is concerned that the buoyancy characteristics of hydrogen would cause hydrogen to collect in the upper head of the PCCS heat exchanger where it could inhibit steam flow through the PCCS. This could lead to higher peak pressures in the containment and could extend the time needed to mitigate the accident. GE has also failed to demonstrate that the TRACG code used in the accident analysis is capable of predicting the performance of the PCCS with hydrogen present.

Until now, GE has maintained the position that testing with helium in an integral test facility is not needed because they (GE) have tested with helium in their separate effects tests at the University of California, Berkeley, and the Massachusetts Institute of Technology. In addition, GE will test using helium in the PANTHERS test facility (separate effects, also). Therefore, GE feels that helium's effect on heat transfer is, or will be, well known. The staff does not dispute this, rather our concern is how a lighter-than-air noncondensible gas would affect the operation of the PCCS system due to its buoyancy characteristics being substantially different from those of nitrogen or air, which are the noncondensible gases being used by GE in their integral test facilities.

The staff, therefore, concludes that there is a need for testing with a lighter-than-air noncondensible gas in an integral test facility for the SBWR, specifically, testing with helium as a simulant of hydrogen. The staff feels that GE needs to perform whatever modifications are necessary to the design of the GIRAFFE, PANDA or some other systems test facility to allow testing with helium in concentrations representative of both design basis accident and severe accident conditions.

Availability of Data for Tests Run on Behalf of GE

Several of the facilities to be used in support of SBWR design certification are operated outside of the GE labs. These include GIRAFFE in Japan, PANTHERS IC and PCC tests in Italy, and PANDA and LINX in Switzerland. The GIRAFFE experiments were the first of these to be completed, but for over a year, the staff's requests for the relevant facility and test data (see enclosure) have not been met. As a result, the staff's review has been delayed. Although GE has taken recent actions to obtain GIRAFFE facility and test data, the staff, requests that GE expedite arrangements for the staff to be provided with all relevant data from the other test facilities. NRC staff is not prepared to send its personnel to visit these facilities for the purpose of searching through files, taking facility dimensions, and viewing relevant documents in order to obtain facility data and experimental results needed for input decks and code validation.

The staff realizes that the impact of these findings may be considerable and that GE may, therefore, require some time to formulate its reply. We urge that you give the findings your careful attention before doing so. The staff is prepared to discuss these issues further at your request. We look forward to meeting with you and hearing your proposals for addressing these issues in a manner that will satisfy design certification regulations.

Testing Requirements of 10 CFR 52.47

Paragraph (b)(2) of 10 CFR 52.47 states that certification of a standard design which utilizes simplified, inherent, passive, or other innovative means to accomplish its safety functions will be granted only if several conditions are met and the supporting information is contained in the design certification application. Unless testing of a suitably sited, full-size prototype plant is conducted [this option is provided by paragraph (b)(2)(i)(B) of 10 CFR 52.47], GE must demonstrate:

- Performance of each design safety feature through either analysis, appropriate test programs, experience, or a combination of these.

- Acceptability of the interdependent effects among the design safety features using analysis, appropriate test programs, experience, or a combination of these.

- Sufficient data exist on the design safety features to assess the analytical tools used for safety analyses over a sufficient range of normal operating conditions, transient conditions, and accident sequences.

It is the staff's understanding that GE does not intend to rely on testing of a suitably sited, full-size prototype plant. Therefore, it is necessary for GE to provide information showing that the above conditions are satisfied. The staff's review of the SBWR testing program has and will continue to be focused on these areas. We require that a comprehensive submittal for the SBWR, which presents your overall testing approach in a manner which more clearly addresses the regulatory requirements and the other staff positions outlined above, be provided in Section 1.5 of the SBWR Standard Safety Analysis Report.

SBWR Review Schedule

The staff is presently reevaluating the the passive plant schedules with the intent of updating the schedules of SECY-93-097, "Integrated Review Schedules for the Evolutionary and Advanced Light Water Reactor Projects," dated April 14, 1993. The nature of the staff's testing program concerns directly impact how the SBWR schedule will be revised. Following further development of our revised schedules and receipt of the Commission's guidance, we expect to prepare a letter to you addressing the SBWR review schedule.

If you would like to discuss these matters further, please contact Melinda Malloy at (301) 504-1178 or Frederick Hasselberg at (301) 504-1141.

Sincerely,

(Original signed by)

Dennis M. Crutchfield, Associate Director
for Advanced Reactors and License Renewal
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Enclosure:
Staff Positions on SBWR
Testing Issues

cc w/enclosure:
See next page

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STAFF POSITIONS ON SIMPLIFIED BOILING WATER REACTOR (SBWR) TESTING ISSUES

Gravity-Driven Cooling System (GDCS) Integral Systems Test (GIST)

Evaluation of GE Nuclear Energy (GE) Document Entitled "Response to NRC Findings on GIST"

This document, dated December 16, 1993, was submitted to the NRC in GE letter MFN No. 235-93 in fulfillment of the commitment made at a meeting between GE and the staff on November 16, 1993, to provide GE's justification for the adequacy of the GIST program as an integral systems test to support design certification for the SBWR. It does not include the quantitative scaling analysis requested for GIST, using the general scaling methodology presented at the November 16 meeting. The report contains essentially the same material presented by GE at the meeting, which was provided to the staff in the form of view graphs, with somewhat more supporting written detail.

The staff has reviewed GE's report and finds that there is still insufficient justification for accepting GIST as the sole integral experimental basis for demonstrating the performance of the passive safety injection system of the SBWR or for validating the TRACG modeling of that system's behavior. The bases for the staff's conclusion are primarily the same as those detailed in previous evaluations of the GIST program: (1) significant design differences between the GIST facility and the current version of the SBWR, including failure to include components or systems that could interact with the passive safety systems and (2) insufficient characterization of facility thermal-hydraulic behavior. A third reason for the staff's conclusion -- that GE has not demonstrate that the scaled tests covered a parametric range similar to that expected in the actual plant -- is supposed to be addressed in the quantitative scaling study that GE has committed to provide. There are also technical and non-technical quality-assurance-related concerns in the GIST program that GE has attempted to address.

GE's arguments for the acceptability of GIST, in spite of the acknowledged design differences and experimental and analytical shortcomings in the program, are based on a narrow interpretation of the purpose of the GIST program. GE has claimed in recent meetings with the staff that GIST was to be used only to "confirm the theoretical feasibility of the GDCS" and to "provide additional data for TRACG qualification, specifically GDCS flow rate and injection time." (This "definition" of GIST's objectives is inconsistent with the full objectives stated in GEFR-00850, "Gravity-Driven Cooling System Integration Systems Test Final Report," which asserts that GIST was designed to "provide a sufficient database to qualify the TRACG code for use in SBWR accident analysis," and goes on to specify test parameters and facility response characteristics compared to TRACG predictions, including "minimum annulus water level in the RPV [reactor pressure vessel], core pressure drop," and "low vessel pressure blowdown.") GE claims further that TRACG is adequately validated for all other aspects of passive safety system performance by virtue of previous experimental programs in other separate effects and integral facilities, and also by using data from existing boiling water

Enclosure

reactors (BWRs). It appears, from the limited analyses of GIST tests that GE has provided, that TRACG did an adequate job of predicting GDCS behavior in GIST. However, there are several underlying problems that raise questions about the capability of TRACG to analyze both GIST and SBWR behavior.

The foremost concern about GIST and associated TRACG analyses and their relationship to the SBWR as currently configured involves the substantial design differences between GIST and the SBWR. The GIST facility represents the GDCS pool and the suppression pool as a single large reservoir, while in the SBWR they are separate, with the GDCS pool at a higher elevation than GIST's combined pool and the suppression pool at a lower elevation. Furthermore, all depressurization valves (DPVs) in GIST exhausted into the GDCS/suppression pool, while in the SBWR the DPVs exhaust to containment, and the safety-relief valves are routed to the suppression pool. Neither the passive containment cooling system (PCCS) nor the isolation condenser system (ICS) was represented in the GIST configuration; both of these systems have the potential to interact with the reactor coolant system (RCS) during an accident. Finally, the communication between the wetwell and the drywell in GIST is not representative of the path between the GDCS pools and the containment in the SBWR. GE claims that the qualification basis for TRACG encompasses the behavior of the SBWR systems in a prototypic configuration. However, GE has not demonstrated that there is an adequate database for TRACG to be able to model the <u>interactions</u> between these various systems in the SBWR. For example, since there was no pressurization of the drywell during DPV operation, nor any communication between the GDCS pool and the drywell, there is no way to demonstrate that TRACG can account for systems interactions that may affect GDCS behavior. The venting of steam into the drywell in the SBWR pressurizes the drywell, leading to operation of the PCCS. The changes in drywell pressure feed back to RCS behavior, in terms of (1) available head to inject water from the GDCS pool, which in the SBWR communicates directly with the drywell, and (2) steam venting rate, through backpressure effects on flow from the depressurization valves (especially at low RCS pressures, during and after the transition to subsonic flow). No experimental data exist with which to validate TRACG modeling of this behavior.

Another interaction not represented in GIST involves the isolation condenser (IC). In the SBWR safety system actuation logic, the IC isolation valves open before the automatic depressurization system (ADS) is actuated. The inlets to the three IC heat exchangers connect to stub lines for the DPVs. Therefore, when the DPVs open, water in the IC lines may be pulled back into the DPV lines. This, in turn, could affect the blowdown rate through those valves, and thus impact the depressurization rate of the RCS and, ultimately, the draining behavior of the GDCS. In responding to this issue, GE claims that the available pressure difference between the IC condensate return line and the DPVs is insufficient to drive flow back into the DPVs. This argument ignores the entrained water droplets in the heat exchanger tubes that would be pulled back into the DPVs. The character of two-phase critical flow is such that a relatively small amount of liquid entrained in steam can have a substantial impact on critical flow rate. The principal point here is that there are no data from GIST capable of addressing this issue.

GE has claimed that these types of effects are "unimportant," based on information from their phenomena identification and ranking table (PIRT) for SBWR, data from other testing programs, scaling considerations, or, in the case of interactions, from mainly qualitative arguments. Except for the case of heat losses (see below), almost no calculations are presented to support the qualitative arguments. For instance, the effect of interactions due to the PCCS is dismissed as "unimportant-containment pressure dominated by air mass location, not heat transfer processes." However, there is a complex series of interactions that involve both containment pressure and pressure distribution, and the variation of those parameters as a function of time. For instance, while heat transfer processes *per se* may not control containment pressure, the redistribution of gas in the containment is dependent upon the timing of the operation of the PCCS, which depends, in turn, on the venting of steam from a break and/or the DPVs into the containment. As discussed above, the containment pressure as a function of time has an impact on the behavior of the ADS at the relatively low RCS pressures represented in the GIST experiments, especially once the flow from the RCS becomes subsonic. The ability to vent sufficient steam from the ADS to keep the RCS at essentially containment pressure, in order to maintain GDCS flow, ultimately determines whether emergency core cooling (ECC) injection from the GDCS can maintain coverage of the core. To argue that the PCCS is unimportant is to ignore these types of "cascading" interactions. Without a sophisticated integral systems analysis, supported by adequate data from test facilities that represent appropriately the configuration being modeled, GE's qualitative arguments cannot be validated.

Aside from the issues related to test facility versus SBWR design, there is no evidence that GE did any testing specifically to determine the baseline thermal-hydraulic characteristics of the facility. These parameters include such items as heat losses; pressure drops and their distributions, including valve characteristics, orifices, elbows/tees, etc.; and critical flow through simulated DPVs. GE has presented arguments to show that heat losses, while not explicitly measured, had negligible effects on system behavior. This evaluation is based on a parametric study using postulated losses up to twice as great as the "average" estimated for the test program. GE's results appear to be reasonable; however, it is not clear from the information presented how the losses were distributed in the parametric study. It is not known at this point whether changing the heat loss distribution (without changing the magnitude) would alter the results of the parametric study. As to pressure drops, pressure drop distribution, and critical flow, no information has been provided by GE to determine how these characteristics were translated into information for use in TRACG. It has not been shown, therefore, how GE was able to get TRACG to calculate the GIST depressurization and flow coastdown rates, and the GDCS injection rate, so accurately. Since the ultimate purposes of an integral test are to demonstrate that (1) the code models can predict the test facility behavior and (2) that the scaling has been done such that the thermal-hydraulic parametric range in the test loop is similar to that in the plant, allowing the results to be "scaled up," GE has not presented evidence that these two objectives were, in fact, satisfied.

As previously noted, GE's definition of the purposes of the GIST program as "[demonstrating] theoretical feasibility of a GDCS" and "[determining] GDCS flow rate and injection time" for TRACG qualification is inconsistent with the original mission of GIST, as discussed in documentation from 1986-87 found in the GIST DRF. If the narrow definition is accepted, however, GIST cannot be considered as an integral systems test, but rather as a separate-effects test of gravity-drain coolant injection. Despite GE's characterization of the test as an "integrated systems test," integral systems behavior was, for the most part, ignored in the test, with the exception of a rudimentary representation of the automatic depressurization system. If GIST is considered as a separate-effects experiment, there exists no integral systems experiment addressing the blowdown/ECC injection phase of an accident in the SBWR. It is the staff's view that a properly scaled and configured integral systems test is essential to support the design certification of the SBWR and they would be interested in GE proposing how they would obtain the needed data, perhaps by modifying new existing facility.

Isolation Condensers

Evaluation of GE's Letter MFN No. 216-93 Dated November 30, 1993, Regarding GE's Position That IC Testing Is Not Needed For SBWR Certification

GE continues to take the position that IC testing in PANTHERS is not required for SBWR design certification. As stated in SECY-92-339, "Evaluation of the General Electric Company's Test Program to Support Design Certification for the Simplified Boiling Water Reactor," dated October 6, 1992, these tests are required to demonstrate the performance of the IC. The reasons for the staff's positions are as follows:

The IC system is the only safety-related system that is capable of removing decay heat at full reactor pressure. It is crucial in transients that involve loss of all ac power. Dependency on IC operation is included in the response to several events analyzed in Chapter 15 of the SBWR SSAR, and credit for ICS operation is explicitly included in GE's Chapter 15 accident analyses for events such as main steam isolation valve closure and loss of feedwater. GE's claim that testing is not required because the IC is not an engineered safety feature (ESF) is, therefore, not relevant since it is used within the design basis envelope to respond to non-loss-of-coolant (LOCA) transients. The claim that "the SBWR can be cooled successfully, including appropriate accounting for single active failures, without the ICS" appears to be true only if the automatic depressurization system is actuated. However, GE's Chapter 15 analyses do not demonstrate the capability of cooling the plant without the ICS, using only safety-related equipment and accounting for a single active failure. No credit can be given in these cases for the operation of non-safety systems, such as the reactor water cleanup/shutdown cooling (RWCU/SDC) system, due to their dependence on the availability of ac power. If the alternative to IC operation is, in fact, use of the ADS to bring the plant to a stable, cooled condition for non-LOCA events, GE must demonstrate through appropriate analyses that this can be accomplished, and must show that these assumptions are consistent with the frequency of actuation claimed for the ADS over the plant lifetime.

GE cites the requirements of 10 CFR 52.47 for testing of safety features and systems interactions and argues that the IC is not an ESF and, therefore, the "testing of safety features" clause does not apply. This regulation does not refer solely to ESFs and the use of the IC to remove decay heat without resorting to depressurization, as assumed in the Chapter 15 analyses, is indicative of its importance. It should also be noted that GE's position regarding the status of the IC is inconsistent with the EPRI Passive Utility Requirements Document, which lists the passive decay heat removal system as an ESF; this inconsistency is not documented in the SSAR.

GE has repeatedly claimed that the fact that some current BWRs use ICs to provide a sufficient demonstration of IC performance. However, no data have been provided to the staff to support GE's position on IC performance, despite repeated promises to do so. In any case, the design of present-day ICs does not resemble the design of that proposed for the SBWR, and furthermore, the SBWR IC employs a unique noncondensible gas vent.

GE's position that it is not appropriate to test hardware (components) as part of the design certification program is inconsistent with its own certification-related testing of the passive containment cooling system (PCCS) heat exchanger. Furthermore, the claim that IC performance can be demonstrated during plant startup overlooks the facts that (a) it is highly unlikely that an in-plant unit will have sufficient instrumentation to obtain detailed operating data and (b) it is unlikely that an in-plant testing program could approach the rigorous thermal-hydraulic and mechanical test regimen planned for the PANTHERS tests.

Irrespective of whether it is classified as an "engineered safety feature," the IC is clearly an essential safety-related system that is assumed to be available to mitigate the consequences of a range of transients. GE has failed to demonstrate that the SBWR can be successfully cooled in such events using only safety-related systems, if the IC operation is not reedited.

GE should, therefore, include the PANTHERS IC tests as part of its design certification testing program. The staff will review in detail the facility design, test specifications, and test matrix for these tests to determine if the program is adequate to provide the data required for design certification.

<u>Performance of the PCCS in the Presence of Lighter-Than-Air Noncondensible Gases</u>

The passive containment coolers (PCCs) are connected to the containment drywell on the supply side and the suppression pool (noncondensible gas venting) or the GDCS pool (condensate return) on the return side. No valves are located in the lines, but the return lines are submerged in the suppression and GDCS pools, respectively.

The depth of submergence is some fraction of the main LOCA vent submergence. When the drywell pressure exceeds the wetwell pressure so as to overcome the submergence, the steam condensate and noncondensible contents of the lower drum will bubble into the GDS pools and the wetwell, respectively. Any residual steam in the noncondensible gas will condense in the pool and the noncondensibles will enter the wetwell airspace. This flow will continue until the wetwell pressurization has reduced the drywell-wetwell pressure differential to a level that is insufficient to overcome the submergence. At this time, the water will reenter the noncondensible vent pipe and the venting or bubbling will cease.

Under normal operating conditions, the PCC will have the drywell inerted atmosphere within the tubes causing a minimum amount of energy transfer to the external pool covering the shell side of the PCC. If a LOCA occurs into the drywell, steam will be driven into the PCC tubes to be condensed on the cooler tube wall. The condensate will drain into the lower drum and into the GDCS pool which is located within the drywell.

If the rupture is small enough, the PCCs may be sufficient to control drywell pressurization to below the main LOCA vent submergence and all the released energy will be transmitted into the external pool. For large breaks, the main LOCA vents to the suppression tanks will be uncovered for a short period of time. When this occurs the suppression pool will condense the entering steam. When the steaming rate decays to the capacity of the PCCs, the main LOCA vents will cover.

The process by which the PCC handles the entering noncondensibles is the issue here: how will the system respond in the presence of hydrogen? Under design basis accident conditions, hydrogen concentrations of about 5 to 6 percent are expected. For metal-water reaction rates of 100 percent, as specified by 50.34(f), hydrogen concentrations exceeding 30 percent are expected.

GE has taken the position that nitrogen is an adequate simulant for hydrogen in an integral test facility, since both gases are noncondensible and the heat transfer properties within the tubes have been established via separate effects tests at the University of California at Berkeley. Therefore, GE argues there is no need for integral tests with a lighter-than-air gas. But these were once-through tube tests, without the low-velocity upper and lower drums nor the purge dump into the suppression pool being simulated.

The staff has reviewed the GIRAFFE test results and finds the behavior of the PCC in the presence of nitrogen does not adequately simulate PCC behavior in the presence of hydrogen. During the GIRAFFE tests, nitrogen had the tendency to sink to the bottom of all of the vessels into which it was introduced. The drywell, for example, showed that a significant amount collected in the lower region. Within the PCCS, it was shown that the nitrogen sank into the lower portion of the vertical tubes and into the lower drum. If, however, the gas was composed of a nitrogen/hydrogen mixture, the performance of the unit could be quite different. The lighter hydrogen might collect in the low velocity field of the upper drum. If this were to occur to any significant degree, the PCC behavior would be different, and probably the air-steam interface within the tubes would be altered.

Furthermore, upon the opening of the vacuum breakers, any hydrogen that has reached the suppression pool would re-enter the drywell and flow up and into the PCCS. The nitrogen, on the other hand, would tend to flow down into the lower drywell. The long term effect on a transient of repeated hydrogen