November 25, 1994

MEMORANDUM TO: John T. Larkins, Executive Director
Advisory Committee on Reactor Safeguards

52-004

FROM: Dennis M. Crutchfield, Associate Director for
Advanced Reactors and License Renewal
Office of Nuclear Reactor Regulation

SUBJECT: DRAFT SAFETY EVALUATION REPORT (SER) ON THE ADEQUACY OF THE TECHNICAL APPROACH TO THE TESTING AND ANALYSIS PROGRAM (TAP) FOR THE SIMPLIFIED BOILING WATER REACTOR (SBWR) DESIGN

In response to a March 7, 1994, letter to GE expressing Office of Nuclear Reactor Regulation (NRR) staff concerns on the SBWR TAP, GE committed to perform a reassessment of the program. GE documented the results of the reassessment, which included both an internal GE review and an external (independent) review, in NEDC-32391P, "SBWR Test and Analysis Program Description [TAPD]." The TAPD was transmitted to NRC for review on August 10, 1994, with a request that the staff evaluate the acceptability of the program described therein. In particular, GE requested staff concurrence that: (1) if the overall TRACG computer code qualification plan and the SBWR test programs (and associated TRACG analyses) are successfully completed, the provisions of paragraphs (1), (2), and (3) of 10 CFR 52.47(b)(2)(i)(A) will be satisfied; and (2) the program can succeed without construction of a new integral systems test facility.

The ACRS Thermal-Hydraulic Phenomena Subcommittee met with GE and the staff on August 24, 1994, to discuss the progress of the SBWR design certification review and to receive an overview of the SBWR TAPD. Since that meeting, GE has proceeded with various testing activities described in the TAPD and the staff has continued its oversight of these activities. In addition, the staff has completed its review of the adequacy of the technical approach documented in the TAPD.

The results of the staff's review are provided in the attached draft SER. We are providing this draft for ACRS review prior to the January 1995 meetings at which we anticipate discussing the details of the staff's conclusions with the Thermal-Hydraulic Phenomena Subcommittee and the Full Committee. Following these meetings, we would appreciate a letter from the ACRS addressing the adequacy of the approach described in the TAPD. Following receipt of the ACRS letter, we expect to prepare a Commission paper on the SBWR TAP and to finalize the SER.

Attachment:
Draft SER on TAPD

Contact:
J.H. Wilson, NRR
504-1108

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RGallo, O-9A1
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SBlack, O-10A19
RGramm, O-10A19
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NRC STAFF EVALUATION OF

GE NUCLEAR ENERGY'S

SIMPLIFIED BOILING WATER REACTOR

TEST AND ANALYSIS PROGRAM DESCRIPTION

(DRAFT)

Attachment

## Introduction

GE Nuclear Energy (GE) has submitted to the Nuclear Regulatory Commission (NRC) an application for design certification of the Simplified Boiling Water Reactor (SBWR). The SBWR is a "passive" plant design, in that operation of safety systems does not require "active," ac-powered components. To support design certification, GE developed a Design Certification Testing Program, to satisfy the requirements of 10 CFR 52.47(b)(2)(i)(A), which states that for a plant that "utilizes simplified, passive, or other innovative means to accomplish its safety functions," the applicant must demonstrate that:

1. The performance of each safety feature of the design has been demonstrated through either analysis, appropriate test programs, experience, or a combination thereof;

2. Interdependent effects among the safety features of the design have been found acceptable by analysis, appropriate test programs, experience, or a combination thereof;

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

The NRC staff began its review of GE's design certification test program in 1991, prior to GE's formal design certification application. In October 1992, the staff issued its preliminary review of the test program in SECY-92-339, "Evaluation of the General Electric Company's (GE's) Test Program to Support Design Certification for the Simplified Boiling Water Reactor (SBWR)" (October 6, 1992). In this document, the staff indicated that it had several concerns regarding the proposed test program that needed to be resolved. These concerns involved such issues as the design of test facilities, scope and range of test matrices, and GE's classification of certain programs as "confirmatory" rather than required for design certification.

Between 1992 and 1994, the staff and GE met several times to attempt to resolve the issues discussed in SECY-92-339. In addition, the staff continued its detailed review of GE's test programs, both those completed prior to the submission of the application and those planned for the future. Progress in resolution of the SECY-92-339 issues was very slow; in addition, the detailed test review raised additional concerns. In a March 7, 1994, letter from Dennis M. Crutchfield, Associate Director for Advanced Reactors and License Renewal, NRR, to Patrick W. Marriott, Manager, Advanced Plant Technologies, GE, the staff detailed testing-related issues, both those remaining from SECY-92-339 and new concerns that it believed needed to be resolved to permit the design certification process to continue.

On April 1, 1994, in response to the staff's letter, GE committed to perform a reassessment of the testing and analysis programs for the SBWR, and to report the conclusions of that reassessment to the staff in 3 to 4 months. The outcome of GE's reassessment, entitled "SBWR Test and Analysis Program

Description," NEDC-32391P, hereinafter referred to as the TAPD report, was submitted to the staff on August 10, 1994.

Summary of Staff's Evaluation of the TAPD Report and Major Conclusions

The staff has reviewed GE's TAPD report, and key conclusions are presented in this section. The detailed evaluation of the revised test and analysis program is provided in the remainder of this report. The testing review was limited primarily to the thermal-hydraulic aspects of GE's programs; elements of test activities related to equipment qualification or acquisition of data on structural performance are not covered in detail. Program elements related to analysis are focused on the application of thermal-hydraulic test data to qualification of GE's TRACG systems analysis code, and demonstration of code applicability to the SBWR. Specific areas where the staff requires further information from GE, or where the staff has concluded that additional work is required by GE, are identified as part of the detailed TAPD report evaluation.

The staff's major conclusions from its review of the TAPD report are:

1. In general, the staff agrees with the approach GE has taken in its test and analysis program reassessment.

2. The TAPD report represents a logical, structured presentation of the elements of GE's test and analysis program. However, a substantial amount of supporting information is required before the staff can come to final conclusions regarding the adequacy of individual testing matrices.

3. The staff requires considerably more information than is available in the TAPD report on the details of the code qualification program for TRACG. Neither the TAPD report nor the code qualification documentation for TRACG that GE has submitted to date provides sufficient information on code models and correlations and their applicability over the range of SBWR thermal-hydraulic conditions, nor has the staff been able to determine from these documents how the test data will be used to quantify uncertainties and biases in the analyses, especially for loss-of-coolant accidents (LOCAs).

4. The staff believes that additional testing and analysis is required to address issues related to passive containment cooling system (PCCS) performance and containment response. Specific concerns include: (a) PCCS performance with lighter-than-steam noncondensible gases and with mixtures of lighter- and heavier-than-steam noncondensibles; (b) PCCS and containment response with a stuck-open vacuum breaker; (c) degradation of PCCS performance through ingestion of debris in the drywell; and (d) potential influence of the passive autocatalytic recombiners (PARs), including interactions between the PARs and PCCS.

5. The staff believes that additional integral systems testing, covering the late blowdown and early emergency core cooling system (ECCS) injection phases of SBWR design-basis accidents (DBAs) is required for design certification. However, the staff believes that the required testing can be accomplished without constructing a new integral facility. Testing

should be performed in an appropriately scaled facility that (a) represents the current design of the SBWR; (b) has the capability of simulating a range of design-basis events, including gravity-driven cooling system (GDCS) line breaks and bottom drain line breaks; and (c) has sufficient power and pressure capability to represent these events prior to the initiation of GDCS injection. The staff believes that one or more of the existing SBWR integral test facilities may be able to meet these criteria; however, modifications and/or additional instrumentation may be required.

6. If modifications to the test and analysis program are made to address the staff's concerns in items 4 and 5 above and if the requisite information on test programs and TRACG qualification and applicability are provided to the staff, the staff believes that TRACG qualification and SBWR design certification are feasible using the TAPD approach.

Brief Description of GE's Test and Analysis Program

GE's overall test and analysis effort comprises five major thermal-hydraulic programs:

- GDCS integrated systems tests (GIST) at GE-San Jose. GIST was a 1/508-volume, full-height facility based on an earlier SBWR design. Tests were run in 1988; GE has used the data to evaluate TRACG's capability to model GDCS initiation time and flow rates during design-basis events.

- Long-term (one hour post-LOCA and beyond) separate- and integral-effects containment cooling tests in the GIRAFFE facility at Toshiba's Nuclear Engineering Laboratory in Kawasaki, Japan. GIRAFFE is a 1/400-scale, full-height facility. Tests have been run since 1990 and further tests are planned to investigate containment-related phenomena during design-basis events.

- Full-scale PCCS heat exchanger (HX) tests in the PANTHERS facility at SIET Laboratories, Piacenza, Italy. Testing began in 1994 and is scheduled for completion by the end of this year. The test objective is to characterize PCCS HX performance under conditions up to its design-basis and using pure steam and mixtures of steam and noncondensible gases (air or helium).

- Full-scale isolation condenser (IC) heat exchanger tests, also at PANTHERS. These tests are scheduled to begin in 1995, with similar objectives to the PCCS tests. Test conditions include pressures up to predicted SBWR anticipated transient without scram (ATWS) levels, and several tests with noncondensible gases.

- Steady-state and transient integral systems tests, related primarily to containment performance, in the PANDA facility at the Paul Scherrer Institute in Wurenlingen, Switzerland. PANDA is 1/25-volume and essentially full height. Objectives of the PANDA program include studies of multi-dimensional thermal-hydraulic containment behavior during long-term post-accident cooling. PANDA is limited to studies of main steam line break (MSLB) events, with most tests designed to begin at scaled conditions equivalent to one hour post-LOCA. Some steady-state tests may be performed in 1994, but most tests, including all transients, will be run in 1995.

In addition to the five major test programs, small-scale, low-pressure, separate-effects tests are being performed, with the main objective of providing data for development and validation of specific heat transfer models to calculate heat exchanger performance, especially with mixtures of steam and noncondensible gases. These tests use single tubes similar in diameter to PCCS and IC tubes and have been run at the University of California at Berkeley (UCB) and at the Massachusetts Institute of Technology (MIT). GE plans to apply heat transfer models developed from these tests to predict the heat transfer performance of both the PCC (low pressure) and IC (high pressure) heat exchangers. Other tests and data, not specifically part of the SBWR program but considered by GE to be applicable to the SBWR, have also been used in the test and analysis programs. Examples include stability test data from Hitachi and the Central Research Institute of the Electric Power Industry (CRIEPI), both in Japan, and plant data, also related to stability, from Dodewaard, a small, natural-circulation boiling water reactor operating in The Netherlands.

Key aspects of the test programs, and the areas of emphasis in the NRC staff's review include test facility design and instrumentation; scaling, if applicable; test matrix; test data handling and reporting; and quality assurance. The staff will also evaluate the use of other data bases to support code qualification efforts.

GE's analysis program is focused on the qualification of the TRACG computer code and demonstration of its applicability to the SBWR. TRACG is a complex systems analysis code, based on the TRAC reactor systems code developed under NRC sponsorship. GE has modified the code and has also added the capability of modeling the SBWR containment. To provide a structure for evaluating the capability of the code to model the behavior of the SBWR and to provide guidance in developing a test program to address areas where the code is weak or inadequately validated, GE has employed the "PIRT" process. A Phenomenon Identification and Ranking Table (PIRT) has been developed for the SBWR; this involves characterization by a panel of experts of the thermal-hydraulic phenomena considered relevant to the SBWR and ranking of the importance of those phenomena for various types of operating conditions, i.e., normal, off-normal, transient, and accident. The modeling and supporting data base for TRACG is then compared to the PIRT and areas where testing is needed are identified. The PIRT process can also serve as a guide for development of scaling analyses, since important phenomena need to be considered in facility scaling; GE has employed the PIRT in this manner, as well.

GE has stated that the experimental data will be used either for direct qualification of the TRACG code or to support code qualification activities. Use of test data for code qualification includes model development, model validation, and nodalization studies. Overall code qualification further includes comparative and sensitivity analyses, including "blind" analyses of selected tests (in which test data other than initial conditions are not made available to the analyst prior to test analysis). For these purposes, it is necessary to choose key system parameters as figures of merit to be able to quantify or bound code uncertainties.

Structure of This Evaluation Report

The staff's evaluation of GE's TAPD report follows closely the structure of the TAPD report itself. GE's PIRT is reviewed to determine if an adequate scope of events has been examined for both reactor systems and containment phenomenology in areas such as LOCAs, non-LOCA transients, and stability. The application of the PIRT to both test program development and to code qualification is evaluated.

The major part of the staff's review has focused on the test program. Needs identified in the PIRT process should be incorporated into specific elements in the test program. In addition, uncertainties in test data must be quantified for use in code qualification. The specific issues identified in the previous section, i.e., test facility design, instrumentation, and scaling; test matrix, including types of tests, ranges of conditions, and explicit objectives of the test program; data handling and reporting; and quality assurance are reflected in the staff's review of each of the five major test programs.

The last part of the evaluation report focuses on the analysis plan. The data base for TRACG qualification is reviewed, with emphasis on the testing done specifically for SBWR design certification. GE's use of the test data is evaluated, from the standpoint of code modifications, which as noted previously, can involve both model development and improved nodalization techniques, and also with regard to the overall application of the code to analysis of test data. This involves comparative analyses (including "blind" analyses) and sensitivity studies, and extension of the code to actual plant calculations. For the plant applications, it is also necessary to quantify code uncertainties and to define specific figures of merit against which to judge code performance.

In its first presentation to the staff on the test and analysis program reassessment and the content of the TAPD report, GE posed three major questions to the staff:

1. Is the test program adequate for qualification of the TRACG code?

2. Is the test and analysis program adequate for design certification of the SBWR?

3. Is construction of a new integral test facility required for additional SBWR testing?

As will be discussed below, there is not sufficient information in the TAPD report to permit an unqualified answer to the first question. The staff's answer to the second question must likewise be qualified, both because of its relation to the first question, and also because there are other facets of the test program beyond acquisition of thermal-hydraulic data, e.g., vacuum breaker testing, squib valve testing, and component structural performance, which are not within the scope of this review. Where specific additional information is required to make a final determination regarding aspects of the test and analysis program, this is indicated in the evaluation report. Finally, the staff does believe that sufficient information exists to evaluate the third question. This will be discussed in more detail later in the report.

Review of GE's PIRT

The PIRT process of phenomena identification and ranking, and specific application of the phenomena identified to the SBWR, are discussed in Sections 2, 3, and 4 of the TAPD report. The process is a systematic identification of key phenomena for both reactor and containment systems, based on consideration of design-basis events, (which, for containment, includes consideration of hydrogen generated from a 100% metal-water reaction). In Section 2, a "top-down" process is used for phenomena identification on an overall system basis. In Section 3, a "bottom-up" process is applied, on a component and/or subsystem basis, to identify SBWR-specific features and phenomena. In Section 4, the two approaches are essentially "merged" to form a composite list of identified and ranked phenomena that GE considers important in evaluating the ability of the test program to address TRACG qualification needs. The staff's comments on the "PIRT" or the "PIRT process" refer to aspects of all three steps (top-down, bottom-up, combination) of GE's procedure.

The process for reactor and containment systems is somewhat different. The reactor systems PIRT requires consideration of a full range of potential accidents and transients, including both LOCA events, non-LOCA events, ATWS, and stability. Containment systems, however, do not come into the picture unless there is an energy release to the containment, which limits the containment-related phenomena essentially to LOCAs and any other events that might require actuation of safety/relief valves (SRVs).

The PIRT process was originally developed as part of the Code Scaling, Applicability, and Uncertainty (CSAU) process for quantitative evaluation of the ability of computer codes to calculate specific types of transients or accidents. The process has been extended to evaluation of phenomena to aid in test program development, facility design and scaling, and so forth. However, the rules for this type of extension of the process have never been well defined. The original application of PIRT started with an experimental data base and established codes. Specific figures of merit were established on which to base a quantified evaluation of the codes against the data. For the SBWR, however, the PIRT process is employed differently, in that it is being used to try to assess where the data base may be insufficient for computer code application to analysis of a specific plant design over a large range of accidents and transients. The implications of this application of the PIRT process are significant, for several reasons, including:

1. GE appears to make the assumption that only phenomena ranked "high" need be considered for code validation/qualification. This is an unproven

assumption, in fact, phenomena ranked "medium" or "low" may also require assessment in the code validation process.

2. There also appears to be a tacit assumption that the answer is known prior to performance of testing; i.e., all pertinent phenomena and systems interactions and their relative importance can be determined before development of a test program. This appears in turn to imply that there is nothing "new" to be learned from test programs; rather, the tests are performed simply to extend or broaden the data base for a range of known phenomena or to "confirm" the judgment used in developing the PIRT.

The staff has reviewed GE's application of the PIRT process as part of SBWR test/analysis program development. GE summarizes the application of the results of the PIRT in Table 3.3-1, where both reactor and containment systems phenomena are evaluated and their resolutions described. The options considered for resolution include (a) use of existing data and technology; (b) TRACG sensitivity studies showing the issue is unimportant; (c) acquisition of test data from an existing facility; and (d) future TRACG analyses. The staff is not prepared to accept the rationale presented for resolution of each issue without a more detailed review of the process. In particular, there are several issues noted as having been resolved through TRACG sensitivity studies, such as (a) interactions between the fuel and auxiliary pool cooling system (FAPCS) and the PCCS; (b) recycling of light noncondensibles; and (c) suppression pool stratification. The staff does not understand how these studies were done, since the modeling capability of TRACG does not appear to be adequate to address these issues. Despite these shortcomings, however, there appears to be a logical process developed for tying the PIRT to the objectives of each major test program.

While the PIRT contains a substantial amount of valuable information, and provides useful guidance in evaluation of the test program and of TRACG validation, the staff notes that additional information is needed in the PIRT and also disagrees with the two apparent assumptions inherent in GE's PIRT development. Specific staff comments are listed below.

1. In addition to evaluating "high" ranked phenomena, as stated in Section 4.0, the staff believes that GE should evaluate the need to consider "medium" and "low" ranked phenomena in the PIRT as part of the code validation process. The staff's interpretation of phenomena ranking in the PIRT process is that the ranking is more appropriately an indication of the required fidelity of specific models, rather than an indication of the necessity of including the phenomenon at all.

2. Based on the staff's experience in evaluating integral-systems experiments on passive plants, the staff believes that it is not possible to anticipate every important phenomenon and system interaction prior to the performance of testing. Unforeseen system behavior can bring new insights or raise new issues with regard to system performance during specific accidents or transients. While the PIRT can provide guidance in the development of a test program, the staff believes that GE relies too heavily on the PIRT as a justification for the test program it has

developed. In the staff's view, PIRT development is an iterative process, in which insights from the testing program are folded back into the PIRT and used to help guide code development. This point and related issues are discussed further below.

3. The description of the PIRT is not sufficiently specific to be able to evaluate its development and application. For instance, on page 2.1-1, GE states that thermal-hydraulic phenomena were ranked in terms of "importance," which is then defined as "the degree of influence on some figure of merit." The specific figures of merit are, however, never explicitly defined on a phenomenon-by-phenomenon basis. In addition, the few-word descriptions of the phenomena are insufficient. Without complete descriptions of the phenomena and the rationale for rankings, it is impossible to evaluate the completeness of the PIRT. Related to this issue is the range of conditions over which data is required. The range of conditions is indicated in a broad sense in the PIRT tables, for instance by dividing accidents into two or three "phases" (e.g., blowdown, GDCS, long-term cooling), and by "checking off" the fact that a model for a particular phenomenon exists in TRACG. However, this does not provide sufficient detail, nor does it differentiate between different types of accidents within a general category in which phenomena may differ; e.g., phenomena in a GDCS line break may differ from those in a bottom drain line break. It also does not demonstrate that the phenomenological models in TRACG cover the range of thermal-hydraulic conditions over which they must be employed to calculate SBWR behavior.

4. GE states on page 2.2-1, "For a complete PIRT evaluation, the entire spectrum of events must be covered, including analyses with less limiting conditions than the design-basis case with no auxiliary power." However, the PIRT presented in the TAPD report still neglects aspects of system response in such cases. For instance, the LOCA/ECCS PIRT does not reflect any phenomena related specifically to isolation condenser performance. Only a vague entry, "isolation condenser interaction" (E7), is included, without an indication of what thermal-hydraulic phenomena such interactions could include. In addition, the elimination from consideration of phenomena related to non-safety systems (e.g., note at bottom of Table 3.2-1) may be inappropriate if these systems can significantly influence safety system performance or overall system accident or transient response.

5. The links between containment-related phenomena and potential effects on ECCS performance are not called out specifically in the PIRT. For instance, reactor safety systems may be initiated by a high containment pressure signal. Effects of condensation on structures in the containment, especially during the early part of an accident, also appear not to be considered.

6. Single failures fall within the scope of design-basis accident evaluation, but there is no indication of degraded component or system performance in the PIRT. The staff is particularly concerned about the effects of a failed-open vacuum breaker on containment response over a range of

accident scenarios. There do not appear to be any plans to obtain performance data on safety systems under these conditions.

7. There appears to be no consideration of debris related to containment safety system performance. For example, debris in the drywell air space could be drawn into the PCCS HXs, clogging the tubes and significantly affecting containment cooling performance.

8. Although GE refers briefly to effects related to the passive autocatalytic recombiners (PARs), this appears not to be regarded as a significant issue. The staff believes there are issues with respect to the PARs that need to be considered, including interactions with the PCCS, since the PARs can induce their own recirculation flow paths and affect flow into the PCCS HXs.

9. There is a lack of recognition of the presence of hydrogen in containment during DBAs. Using the methodology in 10 CFR 50.44, calculated hydrogen concentrations from metal-water reactions can reach about 5 percent. Despite the staff's repeated concerns regarding the impact of light noncondensibles on PCCS performance, there does not appear to be a consistent consideration within the PIRT relative to the PCCS purge/vent process and return to stable operation.

10. There are other areas of containment-related phenomena that appear not to be considered adequately. These include SRV performance, especially with respect to air-clearing loads; and drywell stratification.

11. The staff does not believe that adequate attention has been paid in the PIRT to ATWS events or to stability-related phenomena. Evaluation of phenomena during these events is extremely limited and consideration of the effects of systems interactions is virtually non-existent.

12. A "road map" showing how phenomena identified in the top-down process and in the bottom-up process are translated into entries in the tables in Section 4 would be useful to allow reviewers to track composite PIRT development. The discussion in Section 3 is difficult to follow, since the text and the tables do not appear to be cross-referenced. The review of the composite PIRT is complicated by the absence in Section 3 of the accident types and phases shown in Section 2. In addition, some clarification is needed in Section 3 with regard to "unique features" of the SBWR. For example, "unique RPV [reactor pressure vessel] nozzles" are an entry on page 3.2-3, but the "qualification" column shows that this is covered by the "existing fleet." If the nozzles are a unique SBWR feature, it is not clear how a data base related to the existing fleet is relevant without demonstration that the models/correlations used to predict thermal-hydraulic behavior have been assessed for the SBWR design. (See also item 3 on previous page.)

With regard to items 3 and 12 above, the sample page from the Qualification Database presented on pages 3.2-17 and 3.2-18 is very useful and the staff requests that the complete compilation of this information for the SBWR be provided to the staff to assist in its review.

## Review of GE's Test Plan

This section of the staff's evaluation relates to elements of Sections 5 and 6 and Appendixes A and B of the TAPD report. Section 5 of the TAPD report tabulates the phenomena identified in the composite SBWR PIRT against the available data bases related to thermal-hydraulic modeling of the reactor vessel and core and the containment of the SBWR. The sources of the data can be characterized broadly as separate-effects tests, component tests, integral systems tests, and plant operating data. While the general structure of this section is helpful in matching phenomena (and, ultimately, appropriate TRACG thermal-hydraulic models) against both existing data and results from planned SBWR testing, the information presented suffers from many of the same short-comings identified above for the PIRT process itself. Most important is the lack of discussion or indication of the range of the models and correlations in TRACG and explicit demonstration that the range of the data bases is applicable to SBWR and the absence of any discussion on uncertainties in the data.

In some respects, the logic of the tables in Section 5 is difficult to follow. For instance GE differentiates between separate-effects and component tests in Tables 5.1-2 and 5.2-2, but the subheading for each table reads "Matrix of Separate Effects Tests Qualification Data Base vs. Highly Ranked Phenomena." In most cases, component tests do, in fact, provide separate-effects data and it is not clear why GE has chosen the format in the TAPD report. A table such as that presented on page 5.2-5, with one entry on the entire page, provides relatively little information. There are also inconsistencies between the tables; phenomena not present in one table then appear in subsequent tables. In addition, information in the tables is inconsistent with previous information provided to the staff. For example, phenomenon C26, Critical power for 9 ft. core, is marked as addressed in ATLAS CPR tests, shown as existing data. However, in responses to previous staff requests for additional information (RAIs), GE has indicated that tests will not be performed in ATLAS for the SBWR fuel design until GE has a customer for the SBWR, at which time the specific fuel design chosen will be tested. The applicability of existing ATLAS data and of GE's critical power (CP) correlation to SBWR over the range of conditions (accident, transient, ATWS, etc. for which CP calculations must be performed) remains to be demonstrated. Likewise, the uncertainty associated with use of the data and correlation has not been quantified.

Section 6 of the TAPD report relates primarily to the TRACG qualification plan and will be addressed in further detail in a later section of this report. However, the tables in this section represent a further refinement of the tables in Section 5 and are useful as an integrated look at the information that GE expects to be generated in the SBWR testing program and as a very brief summary of some key test objectives. However, the staff disagrees with "low" priority ranking for the GIRAFFE helium testing shown in Table 6.1-1 (page 6.1-3). The staff considers acquisition of data from integral testing of PCCS performance over a range of noncondensible gas compositions and concentrations to be an essential part of the SBWR testing program.

GE's testing program and applicable scaling analyses are contained in Appendixes A and B of the TAPD report, respectively. In terms of composition, the

SBWR design certification program has not changed in a general sense since the staff's initial review began in 1991. The five major test programs comprising design certification testing remain GIST, GIRAFFE, PANTHERS-PCCS, PANTHERS-IC, and PANDA. However, as part of the TAPD reassessment, GE took a number of steps to respond to issues raised by the staff in SECY-92-339 and in the staff's March 7, 1994, letter. Major GE actions include:

1. The objectives of GIST were "redefined" from those of an integral systems test to the specific areas of providing data on GDCS flow and initiation time.

2. Early data from GIRAFFE was removed by GE from the "formal" SBWR design certification data base, due to concerns expressed by the staff about test program quality assurance (QA). It should be noted that this action was not requested by the staff and the investigation of GIRAFFE QA was never completed. This early data will be used by GE in a "confirmatory" manner, which has yet to be fully defined by GE. GE did commit to perform additional design certification tests in GIRAFFE, however, to address staff concerns regarding the effects of hydrogen (simulated by helium) on PCCS performance.

3. All testing in the PANTHERS-PCCS, PANTHERS-IC, and PANDA programs were explicitly made part of the design certification test program. Previously, GE had maintained that part of the PCCS and PANDA programs and all of the IC program were "confirmatory" in nature and not required for design certification.

4. In addition to upgrading the status of PANDA to "required for design certification," GE expanded the test matrix to include additional transient tests. Furthermore, some tests were identified as beginning "early" in the accident sequence; based on facility power capability, PANDA can represent scaled SBWR conditions at approximately 20 minutes post-LOCA.

The staff agrees that GE has addressed many of the major issues raised by the staff concerning the design certification test program. One significant issue that remains open, however, is the need for additional integral systems testing during the late blowdown and early ECCS injection phases of SBWR design-basis events. This is discussed in more detail below.

The TAPD report does not contain sufficient information to provide an in-depth assessment of the individual test programs. While the TAPD report contains program descriptions, facility design information, broad test program objectives, proposed test matrices, and scaling analyses, details in many of these areas are missing. The staff's test program review requires these details to be able to perform a detailed evaluation. Specific information required includes:

1. Detailed objectives, on a phenomenological basis, for each of the test programs and quantitative justification, related to the range of conditions expected for the SBWR and required for TRACG qualification, for the choice of test conditions.

2. Design details for each test facility. This information will be used to assess the adequacy of the facility to meet its stated objectives and also to provide information to allow the staff to perform appropriate audit analyses of GE's testing.

3. Details of test matrices, where specific conditions are not specified. For example, the PANTHERS-IC test matrix contains tests involving the use of noncondensible gases. However, the concentrations of the noncondensible gases are never specified and there is no indication of the basis that will be used to specify those concentrations, i.e., how the range of concentrations can be related to SBWR conditions.

4. Complete information on instrumentation, i.e., types, locations, ranges, and on data acquisition capability is needed. In addition, GE must specify how errors and uncertainties in the data will be reflected in the use of the data for TRACG qualification. For instance, PCCS performance criteria are based on the rate of steam condensation in the tubes. This rate is measured in the PANTHERS tests indirectly on a global basis only. Thus, an estimate of the uncertainty associated with the application of the correlation based on single-tube heat transfer data may not be possible. Similar considerations may apply to determination of uncertainties associated with the distribution of noncondensible gases.

5. Detailed information on the QA process applied for the test programs.

With respect to items 1 through 4 above, the staff expects this information to be contained in the test specification for each test program.

The fifth item, QA, has become a significant issue for the design certification test program. GE committed, in its contract with the U.S. Department of Energy covering SBWR-related work, to meet the requirements of the American Society of Mechanical Engineers (ASME) nuclear quality assurance standard NQA-1. The staff will continue to conduct QA inspections of design and prototype qualification testing activities at GE's active test facilities in order to assure that the approporiate provisions of NQA-1, or other appropriate standards meeting the requirements of Appendix B to 10 CFR Part 50, are being effectively implemented.

The staff has reviewed the information on the test programs that is contained in the TAPD report and has in some cases compared it to information available in other test-related documentation provided to the staff. Specific issues related to the individual test programs are listed below.

1. PANTHERS-PCCS

   a. The choice of mole fractions of noncondensible gases should be justified. The staff believes that a wider range of mole fractions should be included in the test program.

b. Tests with steam flows higher than 0.015 kg/s (0.033 lbm/s) should be included to address the range of PCCS performance that would exist if one or more PCCS units were out of service at the time of an accident.

c. The staff requires clarification of the test matrix and test procedures for the PCCS tests. Information in the test plan prepared by SIET differs from that in the TAPD report. Also, procedures for "pure steam" tests in PANTHERS appear to differ from those used in the GIRAFFE tests and could affect condenser performance.

d. The staff requires additional information from GE to determine how the test conditions are related to DBA flow conditions over the full range of PCCS operating conditions.

e. The staff considers the most significant tests as those transient tests in which the valve to the vent tank is closed. The resultant transient is equivalent to the actual performance of the PCCS unit. In particular, the staff is most interested in such a test using a mixture of helium and nitrogen.

f. The staff believes that this program can potentially generate an excellent data base with which to assess performance of the PCCS HX. However, more information is required for the staff to understand GE's process for evaluating the test data.

2. PANTHERS-IC

a. As noted previously, detailed information is required on conditions during certain IC tests. Steam and, where appropriate, noncondensible gas flow rates should be specified and justified based on the expected range of SBWR conditions. This includes the possibility, during the latter part of the GDCS injection phase, that noncondensibles could flow back into the reactor vessel from the containment and affect significantly the performance of the IC heat exchangers. The possibility of a build-up of radiolytic hydrogen in the IC also needs to be considered.

b. The staff believes that the range of pressures should be extended to lower values. The IC has the potential to affect water level in the vessel even at low pressures and may have an effect on the actuation of suppression pool injection.

c. The range of pool temperatures should be examined to assure that SBWR conditions are bounded. Any flow restrictions that could affect pool pressure and possibly increase pool saturation temperature could affect IC heat removal and ultimately its effect on system response.

3. PANDA

a. The staff requires clarification of the procedure for running steady-state tests in PANDA, specifically in comparison to the procedures for performing similar tests in GIRAFFE. The detailed procedures for the transient (M series) tests are also required for review.

b. The staff is aware that PANDA is limited to performance of MSLB tests. As part of item 3a., the staff requests information describing how PANDA test conditions could be manipulated to correspond to expected conditions during other design-basis LOCAs.

4. GIRAFFE

a. As noted previously, GE needs to clarify what will comprise "confirmatory" use of GIRAFFE data, especially with respect to TRACG qualification. This applies to all Phase 1 and Phase 2 GIRAFFE data, which the staff believes comprise a valuable data base to aid in SBWR analysis.

b. For both previous and future tests, the thermophysical aspects of the loop, e.g., heat losses, pressure drops, etc., must be characterized. GE and Toshiba should consider adding insulation to the loop to reduce heat losses.

c. The staff commends GE for adding helium tests to the GIRAFFE program. However, the staff has very little information about these tests, beyond knowing that a 100-percent helium test (i.e., the noncondensible gas was helium only) has been conducted and that four additional tests are planned. Detailed information regarding these tests is required for review, related in particular to the capability of these tests to represent key phenomena, such as the PCCS purge/restart cycle and the oscillatory conditions noted in single-tube tests. In addition, the staff believes that additional GIRAFFE tests are needed that use mixtures of lighter-than-steam and heavier-than-steam noncondensibles to investigate realistic effects of vapor ingestion on the PCCS system. Resolution of these issues before the projected February 1995 completion date for the additional tests is essential.

5. GIST

The problems with the GIST program have been discussed extensively in previous documentation. Thermophysical aspects of the facility were not rigorously evaluated and the facility design did not represent either the SBWR design at the time the tests were performed or the current SBWR configuration. Inadequate QA was applied to the test program, further complicating data analysis. In response to the staff's review of both technical and QA aspects of the GIST program, GE "redefined" the objectives of the program to include only acquisition of data on GDCS flow rates and initiation times (the reference to water level in Subsection A.3.1.4.2, page A-11 is inconsistent with information presented to the staff). However, the staff's concerns about GIST have not been resolved by GE's action. The staff still believes that GIST is not an adequate data base to serve as the sole basis for TRACG qualification for the late blowdown and early ECCS injection phases of SBWR design-basis accidents. GIST was incapable of modeling systems interactions that could have a significant effect on system depressurization rate and water level, both of which have a direct effect on GDCS initiation and flow rate. Interactions with the containment (both wetwell and drywell), which can also impact parameters affecting safety system performance, were not modeled in GIST. Although GE has attempted to assess these effects analytically, the exercise appears circular, since there are no data against which to assess TRACG's ability to model the systems interactions that it is being used to calculate.

The staff has reviewed, to the extent possible based on limited information, GE's plans to perform tests in PANDA starting "early" in the LOCA sequence of events. Based on PANDA's pressure capability, "early" corresponds to approximately 10 minutes post-LOCA; however, based on power, the facility can only represent SBWR conditions at about 20 minutes post-LOCA. The staff considers the latter time a better figure of merit for comparison. PANDA is also limited to representation of MSLBs. While GE considers MSLBs to be the limiting accident in terms of containment performance, both GDCS line breaks and bottom drain line (BDL) breaks are more limiting in terms of reactor vessel response, especially minimum water level. The staff has, therefore, concluded that additional integral systems tests are required as part of the design certification test program for the SBWR. The tests should be performed in an appropriately scaled facility that (a) represents the current design of the SBWR; (b) has the capability of simulating a range of design basis events, including GDCS line breaks and BDL breaks; and (c) has sufficient power and pressure capability to represent these events prior to the initiation of GDCS injection. The staff believes that the GIRAFFE facility is the best currently available test loop to meet these requirements, although some modifications and additional instrumentation may be necessary. GIRAFFE has a demonstrated capability to simulate GDCS line and BDL breaks, has a scaled power capability of approximately 4 percent of full power (equivalent to about 1-2 minutes post-scram), and represents all SBWR safety systems. Because of the limitations of PANDA, as described above, the staff considers the use of that facility unlikely to meet the key requirements for the necessary tests. Significant additional justification, or modifications to PANDA (e.g., to upgrade its power and to add the capability to run tests other than MSLBs), however, could make it an acceptable alternative to GIRAFFE. The staff would evaluate any such proposal by GE.

In addition to the five major test programs discussed above, the staff has begun to review the single-tube heat transfer tests conducted at UCB and MIT. GE has determined that the MIT data is somewhat flawed; thus, the UCB data comprises the "preferred" data base. However, the data from the UCB tests represent three distinct types of behavior: (a) tests that quickly reached steady-state conditions; (b) tests that oscillated about a steady-condition, eventually reaching steady state; and (c) tests that oscillated irregularly, never achieving a final steady state. While the last two categories of tests are not mentioned in the TAPD report, the staff is concerned about PCCS performance, should similar behavior be seen in the full-scale heat exchanger, and the potential for deposition of significant amounts of energy in the suppression pool through the main vents. The staff will assess carefully the application of the UCB test data and correlation to analysis of data from the GIRAFFE, PANTHERS, and PANDA programs.

Review of GE's Analysis Plan

Section 6 and Appendix A of the TAPD report address, in part, GE's analysis plan for the SBWR. However, there is very little detail in the TAPD report on the quantitative aspects of the analysis plan. GE states in a general sense how the data base will be compiled employing the PIRT and the SBWR performance analysis in Section 5 to attempt to demonstrate that all relevant SBWR phenomena are covered by either existing data or planned testing. GE also refers in the TAPD report to three major objectives of the design certification test program: (1) model development, (2) model validation, and (3) nodalization techniques.

It is necessary for the staff to review and approve the TRACG code for use in performing licensing-basis analyses to support design certification. The documentation needed for the code review is far too extensive and detailed to be included in its entirety in the TAPD report. Rather, the staff expects to find the necessary details in the TRACG qualification and applicability reports. However, the staff has performed a review of that documentation and, as reflected in numerous requests for additional information (RAIs) that have been forwarded to GE, has found that much of the information required to assess TRACG is not included therein. The staff's review of TRACG has, therefore, proceeded slowly. As noted previously, the key information needs of the staff in this regard are:

1. Details on how the analysis results will be compared to the experimental data, including consideration of experimental errors and uncertainties, and explicit quantification of code uncertainties and applicable figures of merit. GE says in the TAPD report (see, for example, Subsection A.3.1.1.4, page A-5) that "Analysis results will be compared with test data...," without stating a quantitative basis for the comparison.

2. Explicit quantification of the ranges of models and correlations in TRACG used for SBWR analyses and demonstration on that basis that these models and correlations are appropriate for application to SBWR analyses.

3. Scope and range of comparative analyses.

4. Scope and range of sensitivity studies.

5. Description of "blind" analyses of selected tests.

The staff considers timely submission of the information required for the TRACG review to be of high importance. Revised versions of all TRACG qualification and applicability documentation are needed from GE as soon as possible.

## Summary and Conclusions

The staff has reviewed GE's TAPD report for the SBWR. The staff believes that the report provides a very good framework for assessing the testing and analysis requirements for SBWR design certification. However, much information needs to be added to that framework to allow the staff to perform a comprehensive assessment of the design certification test program and of the TRACG qualification program. The information needed by the staff for the comprehensive reviews of testing and analysis has been detailed in the preceding sections.

In addition, the staff concludes that additional testing is required to support SBWR design certification, in two major areas:

1. Containment-related testing is needed to provide integral-effects data related to PCCS performance in the presence of mixtures of lighter-than-steam and heavier-than-steam noncondensible gases; and

2. Integral systems testing is required to provide data for TRACG qualification for the late blowdown and early ECCS injection phases of SBWR design-basis accidents.

As discussed previously, GE posed three major questions to the staff regarding the SBWR test and analysis program when the TAPD report was submitted to the staff for review:

1. Is the test program adequate for qualification of the TRACG code?

2. Is the test and analysis program adequate for design certification of the SBWR?

3. Is construction of a new integral test facility required for additional SBWR testing?

The answers provided in this report can be summarized as follows:

1. If modifications to the test program are made to satisfy the issues raised by the staff in this evaluation and if the additional information identified herein is provided by GE, including a comprehensive description of data evaluation and TRACG model verification and validation, the staff believes that qualification of the TRACG code is feasible.

2. Based on the answer to question 1, with resolution of the staff's concerns and information needs, development of a test and analysis program adequate for design certification is also feasible.

3. As noted above, the staff has concluded that additional integral systems testing is required for SBWR design certification. However, the staff also believes that the additional testing can be accomplished in existing SBWR test facilities (perhaps with some modifications necessary), so that a new integral test facility is not required.