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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Richard Borchardt, Acting Director
Standardization Project Directorate

Subject: **Testing Program Supplement to the Simplified Boiling Water Reactor (SBWR) Application for Design Certification**

Dear Mr. Borchardt:

The enclosed information is provided as an advance draft of material to be submitted in the next supplement to the application for design certification of the SBWR. This is in response to Staff requests that GE provide a summary of the SBWR testing programs and applicable reference material for systems and components unique to the SBWR.

Sincerely,

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SBWR Test Programs

Introduction

As part of the SBWR design effort, GE has conducted extensive testing on those components and systems unique to SBWR that are safety-related. These tests are described below along with how the results are used in qualification of the computer codes used for the design of the plant. The major computer code utilized in all these areas is TRACG (Reference 14). The qualification basis and tests utilized to qualify the code are discussed in detail in Reference 15. The following paragraphs summarize some of the tests performed to cover SBWR specific features. However, the testing basis described in Reference 15 is also directly applicable to SBWR.

The tests summarized here are categorized by the function of the system or component they represent. Table 1 identifies the applicable reference for each test.

A. Inventory Control

A.1 GIST

A key feature of the SBWR design is the Gravity-Driven Cooling System (GDCS). This system provides makeup to the core in the event of a loss-of-coolant accident (LOCA) by draining water from elevated pools into the reactor pressure vessel (RPV). To qualify computer codes to analyze the performance of this system, GE conducted integrated systems tests to demonstrate the performance of the GDCS.

The GDCS Integrated Systems Test (GIST) Facility was built at the GE Nuclear Energy site in San Jose, California. All significant plant features which could affect the performance of the GDCS (e.g., RPV, containment, depressurization system, break flows, etc.) were included in the design. GIST had a one-to-one vertical scale and a one-to-five hundred eight (1:508) horizontal area (or volume) scale of the RPV and containment volumes.

Tests run at GIST provided a qualification base for the TRACG code and also demonstrated the technical feasibility of the GDCS concept to depressurize the RPV to sufficiently low pressures to allow reflood via a gravity-fed emergency core cooling system. Four accident types were modeled at GIST; three LOCAs (main steam line, GDCS line, and bottom drain line) and a no break (isolation event) transient with loss of inventory. Data from these tests were used to qualify the TRACG code (the GE version of TRAC-BWR) for SBWR applications.

A.2 DPV

The successful operation of the GDCS depends on lowering the RPV pressure sufficiently to allow gravity-fed reflood. In addition to standard BWR safety-relief valves (SRVs), the SBWR also has depressurization valves (DPVs). These squib-operated valves ensure a diverse means of RPV depressurization for all accidents where GDCS operation is required to provide core makeup.

GE conducted a development test program to develop, design, build, and provide test data to qualify a DPV for the SBWR. As part of the test program, prototype valves were used in flow and reaction load tests. These tests confirmed that the DPV can be simply supported as a cantilever off the main steam line or the RPV. They also confirmed that the design will meet the flow requirements for the valve.

Environmental Qualification (EQ) dynamic loads tests were conducted to qualify the valve. These tests simulated conditions the DPV (with components aged to end-of-life) would be subjected to while sustaining plant flow and pipe induced vibrations. These tests modeled the vibrations the DPV would undergo during normal plant operation, SRV cycling, seismic events, and chugging events, and confirmed that the DPV, when called upon by an actuation signal, will perform its safety function for the SBWR.

A.3 PANTHERS - IC

The SBWR will use isolation condensers (ICs) to provide inventory control for isolation transient events. The ICs will take steam from the RPV, condense it, and return the condensate to the RPV. The heat removed will be deposited in an outside containment pool (IC Pool) which is open to the atmosphere. The IC System in SBWR is similar in design to others found on some operating BWR plants; therefore, system operation does not need to be tested.

The SBWR IC is a vertical tube heat exchanger with vents (normally closed) going to the suppression pool. Since the design of the condenser unit is different from existing units, which have horizontal tubes, a prototype condenser will be built and tested. This test program is part of the PANTHERS Test Program. Tests on a full-size IC module will look at the thermal hydraulic performance of the unit, as well as the structural performance to ensure that the condenser will meet the 60-year life of the SBWR. The tests will be conducted in Piacenza, Italy by SIET and are scheduled for late 1994.

GE does not consider the completion of these tests as necessary for SBWR certification. These component tests will confirm that the selected IC design will satisfy the SBWR performance requirements and provide data to quantify the margin above those requirements.

B. Containment Cooling

The SBWR uses a Passive Containment Cooling System (PCCS) to provide heat removal from the containment during a LOCA. The PCCS consists of a Passive Containment Condenser (PCC) which draws steam and nitrogen from the drywell airspace, condenses the steam, returns the condensate to the drywell into the GDCS Pools, and vents the non-condensable gases to the wetwell through the suppression pool. All lines in the PCCS, steam inlet, condensate, and vent, are always open during normal plant operation, as well as LOCA events. The PCCS performs the same function for the containment as the IC System does for the RPV.

An extensive test program has been conducted to qualify the system for SBWR design. These tests include studies on tube condensation with steam/gas mixtures, integrated systems testing, and component testing and are described below.

B.1 Single Tube Condensation Tests

At the Massachusetts Institute of Technology (MIT) and the University of California at Berkeley (UCB) tests were conducted on condensation in vertically oriented tubes.

The MIT and UCB test programs were initiated in order to develop a heat transfer correlation for steam condensation that can be used in the TRACG analysis of the SBWR PCCS condensers. The effective heat transfer in the condensers is dependent on both shear enhancement and noncondensable gas effects. Previously published studies in this area have considered the effects of noncondensable gases, but they have mainly dealt with external surfaces and report only average heat transfer coefficients. These studies provide the local heat transfer coefficient for steam condensation inside of tubes. The noncondensables considered are air and helium representing, respectively, nitrogen and hydrogen in the SBWR containment. A correlation based on the completed test data has been incorporated in TRACG. Additional tests are being conducted in 1993 to provide confirmation of previous results.

B.2 GIRAFFE

Tests have been conducted on separate effects and integral systems effects for the PCCS at the GIRAFFE Test Facility at Toshiba, Japan. The objectives of the GIRAFFE testing program were to provide separate effects and integral systems test data for qualification of TRACG, the computer code which will be used for analysis of the SBWR containment. The separate effects tests addressed the issues of steam condensation heat transfer rates from a steam-nitrogen mixture under steady-state conditions, and of venting of noncondensable gases from PCCS to the suppression pool. Test were conducted using a full-height three-tube condenser to represent the PCC. For the venting study, the nitrogen vent line of the scaled-down heat exchanger was submerged by 0.40m, 0.65m, and 0.90m.

The integral tests demonstrated the concept of the PCCS and provide data for a variety of LOCA simulations, against which TRACG models for the containment have been qualified. The GIRAFFE Test Facility consisted of a full-scale vertical and 1:400 scale volume representation of the SBWR. Key scaled components included the RPV and containment volumes. The initial conditions for the long-term integral tests corresponded to those at one hour after LOCA occurrence. The main steam line break, GDCS line break and bottom drain line break LOCAs were simulated during the long-term system response tests. Data from these tests were used to qualify the TRACG code for SBWR applications.

B.3 PANTHERS - PCC

At PANTHERS, a full-scale prototype PCC will be tested under simulated conditions representing a broad range of operating conditions. These tests will be conducted at the same facility in Italy as that for the PANTHERS IC tests. The major objective of these tests is to confirm, for the PCC, the thermal hydraulic performance for the SBWR service conditions. A series of tests representing a range of steam/air mixtures are scheduled for late 1993 with the test report to be issued soon after.

Following those initial performance tests, more tests will be conducted in early 1994 to gather additional thermal hydraulic performance data and structural data to qualify the design for the 60-year service life of the SBWR. GE does not consider the completion of these additional tests as necessary for SBWR certification. These component tests will confirm that the selected PCC design will satisfy the SBWR performance requirements and provide more data to quantify the margin above those requirements.

B.4 PANDA

The Paul Scherrer Institute (PSI) of Switzerland is building an integral systems test facility (PANDA) which will demonstrate PCCS performance on a larger scale than GIRAFFE. The facility will be full-scale vertical and 1/25 scale by volume. The overall objectives of these tests are to demonstrate that the containment long term cooling performance is the same in a large scale system as previously demonstrated at a smaller scale (GIRAFFE) and that with non-uniform drywell conditions, no significant adverse effects are introduced on the performance of the PCCS.

The test series at PANDA will consist of two main steamline (MSL) break tests. The first test will duplicate the initial conditions of the GIRAFFE MSL break test with uniform drywell conditions and the second will have non-uniform conditions in the drywell. These tests will demonstrate the adequacy of the tests at GIRAFFE and are scheduled to be performed by mid 1994. These tests are not considered necessary for further TRACG qualification and certification, but are being performed to quantify the margins in the qualified TRACG code, which has been qualified using several facilities at different scales.

C. Transients and Normal Operation

C.1 PANTHERS - IC

The use of the Isolation Condenser (IC) to control reactor inventory during isolation events and the role of the PANTHERS IC test program were discussed earlier in Section A.3.

C.2 Plant Startup

The SBWR starts up from low pressure under natural circulation conditions. It has been suggested that geysering could be a potential problem during startup. Here, geysering refers to flow oscillations induced by condensation of vapor from the core in a subcooled upper plenum, resulting in flow reversals in the channels. This instability may cause startup delay if it occurs, but is not related to plant safety.

Tests were used to assess the capability of TRACG to predict this behavior. Results of the TRACG analysis of the test data were reported in Section 5.6 of Reference 15. From this analysis, it was concluded that TRACG successfully calculated the geysering oscillations seen in the experiment and was qualified to predict this phenomena, if it occurs in the SBWR startup.

In Appendix 4D.3 of the SBWR SSAR the test data from Hitachi's small scale natural circulation test loop were also presented. In this test Freon was used as a coolant.

Additional justification for the SBWR startup procedure is based on the Dodewaard reactor, a natural circulation BWR with a 183 MW thermal power rating. Initial startup of the reactor was in 1969. Since then, it has been continuously operating. During the recent two startups (February and June1992) various plant parameters have been measured and recorded, which included recirculation flow, incore steam velocity, reactor pressure, reactor power, downcomer subcooling, reactor thermal hydraulic stability, etc. No indications of reactor instability have been observed. The startup experiences and data were presented in Reference 28.

C.3 Boron Mixing

The SBWR utilizes a standby liquid control system that injects boron into the reactor vessel to provide a diverse means to shutdown the reactor. Reference 24 provides the justification for the use of the boron injection location and mixing in the SBWR.

Table 1

SBWR Testing

FUNCTION	TEST PROGRAM	APPLICABLE REFERENCES
Inventory Control	GIST	15, 16, 22, 24, 25
	DPV	23, 24
	PANTHERS - IC	12, 24, 25, 27
Containment Cooling	Single Tube Condensation	1, 2, 3, 4, 5, 6, 14, 24, 27
	GIRAFFE	8, 9, 10, 11, 15, 16, 24, 25, 27
	PANTHERS - PCC	12, 17, 18, 19, 20, 21, 24, 25, 26, 27
	PANDA	13, 24, 25, 27
Transients and Normal Operation	PANTHERS - IC	12, 24, 25, 27
	Boron Mixing	24
	Plant Startup	15, 28

SBWR Testing Documentation References

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3. "The Effects of Noncondensable Gases on Steam Condensation under Forced Convection Conditions", Mansoor Siddique; Doctor of Philosophy Dissertation, Massachusetts Institute of Technology, January 1992.

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18. SIET Schematic 0094 RI 91, Rev. C

19. Technospecial Drawings, TS 122, Rev. 1; TS 123, Rev. 1; TS 124, Rev. 1

20. SIET Drawing, 24.02.03, Rev. C

21. Technical Specification for PCC Instrument Installation, SIET, 00157 ST 92, Rev. A

22. "Simplified Boiling Water Reactor (SBWR) Program Gravity Driven Cooling System (GDCS) Integrated Systems Test - Final Report", P.F. Billig; GE Nuclear Energy, Document GEFR-00850, October 1989.

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