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BWR Blowdown/Emergency Core Cooling Twenty-First Quarterly Progress Report January 1 — April 17, 1981

Prepared by S. A. Domning

Nuclear Engineering Division
General Electric Company

Prepared for
U.S. Nuclear Regulatory Commission

and
Electric Power Research Institute

and
General Electric Company

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NOTE: Previous reports issued in this series are listed in Appendix B.

CONTENTS

ABSTRACT

Blowdown/Emergency Core Cooling work completed in the first quarter of 1981 (January 1, 1981 - April 17, 1981) is summarized. Preparation of the topical reports for the TLTA large break, small break, and low flow, bundle uncovery (boil-off) tests continued. The final drafts of the small break and boil-off reports were completed. A final review was made on the FIST work scope, and final approval to proceed with this program was achieved on April 17, 1981.

The Twenty-First Quarterly Progress Report is the last in a series of twenty-one BD/ECC quarterly progress reports. These reports document the progress throughout the BD/ECC Program and the transition from the BD/ECC1A phase to the FIST Program.

Section 1

INTRODUCTION

1.1 GENERAL

A major requirement in the design of power reactor systems is the limitation of fuel cladding temperatures below specified values during both normal operation and an unlikely, but postulated, loss-of-coolant accident (LOCA). To meet this design requirement, it is necessary to be able to predict system performance during a LOCA. Since this type of information is not obtainable from tests on actual reactors, scaled system test programs are used to provide basic system performance information. The Boiling Water Reactor (BWR) Blowdown/Emergency Core Cooling (BD/ECC) Program (1) extends the scope of the BWR Blowdown Heat Transfer (BDHT) Program to include ECC system operation. Results from the BD/ECC Program will provide a basis for evaluating BWR system phenomena throughout the entire LOCA transient from break initiation to core reflood.

1.2 PROGRAM OBJECTIVES

The BWR BD/ECC Program charter is to conduct an experimental program, jointly funded by the U.S. Nuclear Regulatory Commission (USNRC), Electric Power Research Institute (EPRI), and General Electric (GE), to obtain information on transient heat transfer following an unlikely, but postulated, rupture of a steam line or recirculation line in a BWR. This program will:

1. obtain and evaluate basic BD/ECC data from test system configurations which have calculated performance characteristics similar to a BWR with 8x8 fuel bundles during a hypothetical LOCA; and

2. determine the degree to which models for the BWR system and fuel bundles describe the observed phenomena and, as necessary, develop improved models which are generally useful in improved LOCA analysis methods.

Requirements of the BWR BD/ECC Program include use of a test apparatus which will provide LOCA test conditions representative of the environment expected in the postulated BWR LOCA. The scaling and design objectives are to provide a test apparatus for investigating, on a real time basis, the expected BWR fuel

thermal-hydraulic response, using an electrically heated, full-size, full-power test bundle.

1.3 ORGANIZATION OF THE PROGRAM

The BD/ECC Program contract was executed in December 1975. The total BD/ECC Program work scope is shown in Appendix A. A report schedule is contained in Appendix B.

1.4 STATUS OF THE PROGRAM

A number of the completed and reported major milestones are presented below. The significant publications pertaining to these milestones are indexed in Appendix B.

1. Formulation of program plan (1) and 8x8 BDHT test plan (2) (Task AA).*
2. An evaluation of electric heaters for use in the BD/ECC Program (Task BB).
3. Issuance of report on the transient thermal-hydraulic model, MAYU04 (3).
4. Distribution of facility description report (4) for the BD/ECC1A phase.
5. Issuance of revised BD/ECC1A test plan (5).
6. 64-Rod Bundle Test Topical Report completed (6).

During the first quarter of 1981, the first draft of the TLTA large break topical report and the final drafts of the TLTA small break and low flow, bundle uncovery (boil-off) topical reports were completed. The scope of work for the Full Integral Simulation Test (FIST) Program has been increased to include additional heat loss tests, more analytical effort in scaling and data evaluation, and incorporation of a system to provide heated feedwater.

A final review was made on the FIST Program work scope and documentation. Final agreement was achieved and a contract modification for the FIST Program was executed with an effective initiation data of April 17, 1981. This quarterly report, which actually encompasses 3-1/2 months, is the last quarterly report to be issued as part of the BD/ECC Program.

*See Appendix A for task description.

Section 2

PROGRAM PLANNING AND ADMINISTRATION

During the quarter, agreement was reached by the program sponsors to increase the scope of work under the proposed FIST Program. The increase includes the addition of the capability to provide feedwater at the typical BWR feedwater temperature, an expansion of the test series to quantify FIST system heat losses over a wider range of conditions, and an augmentation of the analysis effort in both the facility scaling evaluations and in data evaluation. The FIST description was upgraded to reflect these changes and the cost estimate was revised accordingly. The proposed workscope for the FIST Program was also modified.

A final review was made on the FIST Program work scope and documentation requirements. There were no remaining issues regarding the technical content of the FIST Program at the Program Management Group (PMG) meeting held in Washington, D.C., on March 11, 1981. The contract modification for the FIST Program was completed, and the effective initiation date is April 17, 1981.

Section 3

EXPERIMENTAL WORK

3.1 BD/ECC1A TESTING

No tests were performed in the first quarter, and no further testing is planned in the present TLTA configuration.

Section 4

ANALYTICAL EFFORT

The focus of the analysis effort was on preparing the topical reports for the TLTA large break, small break, and boil-off tests. The first draft of the large break report and the final drafts of the small break and boil-off reports were completed by the end of this quarter.

Section 5

TWO-LOOP TEST APPARATUS

5.1 TEST SECTION DESIGN AND FABRICATION

The dismantlement of the TLTA is planned for the second quarter of 1981, and any parts in good condition will be salvaged for possible use in the fabrication of the FIST facility.

Section 6

REFERENCES

1. R. J. Muzzy, Preliminary BWR Blowdown/Emergency Core Cooling Program Plan, General Electric Company, June 1976 (GEAP-21255).

2. J. P. Walker, BWR Blowdown/Emergency Core Cooling Program - 64-Rod Bundle Blowdown Heat Transfer Test Plan, General Electric Company, September 1976 (GEAP-21333).

3. W. C. Punches, MAYU04 - A Method to Evaluate Transient Thermal Hydraulic Conditions in Rod Bundles, General Electric Company, March 1977 (GEAP-23517).

4. W. J. Letzring, Editor, BWR Blowdown/Emergency Core Cooling Program Preliminary Facility Description Report for the BD/ECC1A Test Phase, General Electric Company, December 1977 (GEAP-23592).

5. J. C. Wood and A. F. Morrison, BWR Blowdown/Emergency Core Cooling Program - 64-Rod Bundle Core Spray Interaction (BD/ECC1A) Test Plan, General Electric Company, February 1978 (GEAP-NUREG-21638A).

6. W. S. Hwang and B. S. Schneidman, Editors, BWR Blowdown/Emergency Core Cooling Program - 64-Rod Bundle Blowdown Heat Transfer (8x8 BDHT) Final Report, General Electric Company, September 1978 (GEAP-NUREG-23977).

Appendix A

WORK SCOPE FOR BD/ECC PROGRAM - CONTRACT NO. NRC-04-76-215

PURPOSE

OVERALL PURPOSE

The purposes of the EPRI/NRC/GE Integral Blowdown/Emergency Core Cooling, BD/ECC, test program are to:

1. obtain and evaluate basic BD/ECC data from test system configurations which have calculated performance characteristics similar to a BWR with 8x8 fuel bundles during a hypothetical LOCA; and

2. determine the degree to which models for BWR system and fuel bundles describe the observed phenomena, and as necessary, develop improved models which are generally useful in improved LOCA analysis methods.

SPECIFIC OBJECTIVES

The specific objectives of the integral BD/ECC interaction test program are:

1. Scaling Analysis: evaluate and document the scaling basis of the TLTA in the configurations selected for BD/ECC interaction tests as compared to reference BWR designs.

2. 7x7 Counter-Current-Flow-Limited (CCFL) Flooding Characteristics: conduct CCFL flooding characteristic tests of the present TLTA bundle geometry to establish the need, or lack thereof, to modify the present test apparatus design for the initial BD/ECC interaction experiments.

3. 8x8 Blowdown Heat Transfer Tests: conduct 8x8 BDHT tests for comparison with 7x7 BDHT data and to serve as a BDHT base line for BD/ECC interaction experiments.

4. BD/ECC Interaction Tests: evaluate system response and heat transfer and evaluate effectiveness of ECC during the blowdown period, and extending well beyond the initial flow coastdown and lower plenum flashing periods of the calculated BWR-LOCA in one or more system configurations.

5. Alternate Power Shape BD/ECC: determine the effects of axial power shape on the system response and bundle heat transfer behavior during the calculated BWR LOCA.

6. Non-Jet Pump Plant BD/ECC: investigate the ECC interaction with the system during blowdown in a representative non-jet pump test system configuration.

7. Reporting of Data: report all data (including pertinent error bands) in conventional parametric form suitable for correlation by others.

8. Model Development: develop, verify, and document an improved bundle thermal-hydraulic model that can be incorporated into analyses of BWR LOCAs.

9. Application of Data: specify how General Electric intends to use the data to qualify the degree of conservativeness of BWR LOCA evaluation models.

SCOPE

Task AA - Program Planning and Administration

1. General Electric will prepare a Preliminary BD/ECC Program Plan that elaborates on the means for meeting the program objectives. The program plan will include, but not be limited to: (a) BWR configurations and LOCA conditions to be tested; (b) test parameters and their ranges; (c) updated conceptual designs and testing strategies; (d) an outline of model development and verification activities; and (e) the method of relating previous 7x7 rod bundle data to the 8x8 rod bundle data. Sufficient discussion of the above items will be included to substantiate the basis for the preliminary program plan. The program plan will also include an updated schedule, a proposed data verification and reporting plan, and the planned utilization of data by General Electric to assess current BWR LOCA evaluation methods.

   The preliminary program plan will be provided for EPRI and NRC review, comment, and approval on an agreed upon time schedule. If comments are not supplied to General Electric by NRC or EPRI within the agreed schedule, General Electric may proceed as proposed.

2. Following mutual agreement on the results from Task AA-1, and the appropriate phase of Tasks BB and CC-1, General Electric will prepare a detailed test plan for each major testing phase. Each detailed test plan will include the test objectives, test phase description, test matrices, parameter ranges and reasons for selection, test execution plan, planned utilization of the data, and the planned schedule for completing that phase.

   The preliminary test plans will be provided for EPRI and NRC review, comment, and approval on an agreed upon time schedule. If comments are not supplied to General Electric by EPRI or NRC within the agreed schedule, General Electric may proceed as proposed.

Task BB - Heater Evaluation

1. Perform appropriate analysis relating electrical heater performance to predicted nuclear fuel and temperature performance during an ECC transient. This analysis will describe the method of programming initial and decaying electrical power to produce representative BWR LOCA thermal response and describe how differences in thermal properties are accounted for in the electrical simulations.

2. Evaluate the need for tests to demonstrate the validity of the above analyses. The heater evaluation including documentation of the above item will be provided for EPRI and NRC review, comment, and approval on an agreed upon time schedule. If comments are not supplied to General Electric by EPRI or NRC within the agreed schedule, General Electric may proceed as proposed.

Task CC - Test Facility Design and Fabrication

1. Scaling and design analyses to define each system configuration will be performed and documented. Particular attention will be given to attaining a real t[illegible]simulation of calculated BWR system and fuel bundle thermal-hyd[illegible] LOCA response.

   Design trade-off [illegible] scaling compromise studies will be performed to establish the fi[illegible]caling basis to be used for design and operation of each configu[illegible]on. Appropriate analytical methods including, but not necessarily limited to, those used for BWR performance analyses will be applied to obtain best estimate performance predictions of the BWR reference plants and the test system configurations. These pretest predictions will include time to boiling transition (BT), lower plenum flashing effects, post-BT heat transfer, and response to ECCS operation. Differences in anticipated dynamic response of the test apparatus as compared to a BWR will be identified by appropriate analysis. Measurement requirements to obtain program objectives, including type, number, location and accuracy of instruments, will be specified and an instrumentation plan to meet these requirements will be developed. A preliminary Facility Description, including documentation of the above items, presenting the technical basis for the preliminary design, will be provided for EPRI and NRC review, comment, and approval on an agreed upon time schedule. If comments are not supplied to General Electric by EPRI or NRC within the agreed schedule, General Electric may proceed as proposed.

2. Upon resolution of comments, if any, the contractor shall provide a revised Facility Description as necessary.

   The final design and procurement of necessary material for each configuration will be completed and the system will be prepared for calibration testing.

Task DD - Test Section Design and Evaluation

Upon completion of Task BB and an evaluation of the BDHT test section countercurrent flow limiting (CCFL) characteristics, General Electric will complete the design, procurement, and assembly of the 8x8 rod test sections for BD/ECC testing. The test section designs will be documented in the appropriate Facility Description reports.

Task EE - System Startup Tests

Upon assembly of each configuration, conduct performance and flow calibration tests. Perform hydrostatic, hydrodynamic, and transient startup tests for each

configuration to establish system operational characteristics including adequacy of heater and instrumentation response. Conduct steady-state and/or transient separate effects tests necessary to provide the basis for interpretation of BD/ECC experimental results.

Task FF - BD/ECC Interaction Tests

For each configuration, perform tests as detailed in Tasks AA-2 and CC-2.

Task GG - Data Evaluation and Model Development

1. Analyze and document the as-built system performance characteristics based on system startup tests. Evaluate the test apparatus design for meeting program objectives on the basis of system startup performance tests. Determine what, if any, minor modifications and/or adjustments should be made on the test facility and update the predictions of system response as appropriate.

2. Upon completion of a specified test series, reduce, evaluate, and report the experimental data. Provide the experimental basis for confirming or modifying the assumptions and models used in LOCA evaluations, such as the onset of boiling transition (BT), the subsequent heat transfer rates, effects of lower plenum flashing on core thermal response, and the effects of ECC on core and system response. Document the data obtained, the storage format, and how it can be accessed by others.

3. As appropriate, develop and document improved analytical models, which can be incorporated into best estimate analyses of BWR LOCAs. This will include, but not be limited to, the development of a self-standing transient thermal-hydraulic model for the prediction of local thermodynamic parameters in rod bundles during LOCAs. These local parameters are necessary for the phenomenological understanding and correlation of local heat transfer coefficients. Values for local heat transfer coefficients are desired which may be expressed as a function of local conditions such as temperature differences, flow rates, pressure, and quality.

4. Indicate how the data obtained can be used to assess current BWR LOCA evaluation models including a quantitative determination of safety margins.

Appendix B

BD/ECC PROGRAM REPORTS

B.1 REPORTS PREPARED AS PART OF THE BWR BD/ECC PROGRAM DOCUMENTATION

Report No./Type	Title/Author(a)	Principal Contents
GEAP-21207 Informal	BWR 8x8 Fuel Rod Simulation Using Electrical Heaters, J. P Dougherty, R. J. Muzzy, March 1976.	Analysis of electrical heaters to simulate nuclear fuel rods.
GEAP-21304-1 Quarterly	BWR Blowdown/Emergency Core Cooling First Quarterly Progress Report, January 1 - March 31, 1976.	
GEAP-21255 Topical Report	Preliminary BWR Blowdown/Emergency Core Cooling Program Plan, R. J. Muzzy, June 1976	Design consideration leading to various test configurations. Test parameters and ranges. Test strategy.
GEAP-21304-2 Quarterly	BWR Blowdown/Emergency Core Cooling Second Quarterly Progress Report, April 1 - June 30, 1976.	
GEAP-21333 Topical Report	64-Rod Bundle BDHT Test Plan, J. P. Walker, September 1976.	Test matrix and test strategy for 8x8 plan.
GEAP-21304-3 Quarterly	BWR Blowdown/Emergency Core Cooling Third Quarterly Progress Report, July 1 - September 30, 1976.	
GEAP-21304-4 Quarterly	BWR Blowdown/Emergency Core Cooling Fourth Quarterly Progress Report, October 1 - December 31, 1976.	
GEAP-21304-5 Quarterly	BWR Blowdown/Emergency Core Cooling Fifth Quarterly Progress Report, January 1 - March 31, 1977.	
GEAP-23517 Topical Report	MAYU04 - A Method to Evaluate Transient Thermal Hydraulic Conditions In Rod Bundles, W. C. Punches, March 1977.	Describes the technical basis for a one-dimensional, single channel thermal hydraulic computer code.
GEAP-21304-6 Quarterly	BWR Blowdown/Emergency Core Cooling Sixth Quarterly Progress Report, April 1 - June 30, 1977.	

Report No./Type	Title/Author(s)	Principal Contents
GEAP-21304-7 Quarterly	BWR Blowdown/Emergency Core Cooling Seventh Quarterly Progress Report, July 1 - September 30, 1977.	
NEDG-NUREG-23732	TLTA Components CCFL Tests, D. D. Jones, December 1977.	Results of CCFL testing of TLTA-1 and -3 core inlets and TLTA jet pump. Results of single phase liquid pressure drops across TLTA-3 core inlet and single-phase reverse flow steam pressure drops across TLTA jet pumps.
GEAP-23592	BWR Blowdown/Emergency Core Cooling Program Preliminary Facility Description Report for the BD/ECC1A Test Phase, W. J. Letzring, editor, December 1977.	Detailed description of TLTA Configuration for BD/ECC1A.
GEAP-NUREG-21304-8	BWR Blowdown/Emergency Core Cooling Eighth Quarterly Progress Report, October 1 - December 31, 1977.	
GEAP-NUREG-21304-9	BWR Blowdown/Emergency Core Cooling Ninth Quarterly Progress Report, January 1 - March 31, 1978.	
GEAP-NUREG-21638A	BWR Blowdown/Emergency Core Cooling Program 64-Rod Bundle Core Spray Interaction (BD/ECC1A) Test Plan, J. C. Wood and A. F. Morrison, February 1978.	Test matrix and test strategy for BD/ECC1A phase.
GEAP-21304-10 Quarterly	BWR Blowdown/Emergency Core Cooling Tenth Quarterly Progress Report, April 1 - June 30, 1978.	
GEAP-21304-11 Quarterly	BWR Blowdown/Emergency Core Cooling Eleventh Quarterly Progress Report, July 1 - September 30, 1978.	
GEAP-NUREG-23977	64-Rod Bundle Blowdown Heat Transfer (8x8) Final Report, September 1978.	Topical report covering blowdown heat transfer.
GEAP-NUREG-21304-12	BWR Blowdown/Emergency Core Cooling Twelfth Quarterly Progress Report, October 1 - December 31, 1978.	
GEAP-NUREG-21304-13	BWR Blowdown/Emergency Core Cooling Thirteenth Quarterly Progress Report, January 1 - March 31, 1979.	

Report No./Type	Title/Author(s)	Principal Contents
GEAP-NUREG-21304-14	BWR Blowdown/Emergency Core Cooling Fourteenth Quarterly Progress Report, April 1 - June 30, 1979.	
GEAP-NUREG-21304-15	BWR Blowdown/Emergency Core Cooling Fifteenth Quarterly Progress Report, July 1 - September 30, 1979.	
GEAP-NUREG-21304-16	BWR Blowdown/Emergency Core Cooling Sixteenth Quarterly Progress Report, October 1 - December 31, 1979.	
GEAP-NUREG-21304-17	BWR Blowdown/Emergency Core Cooling Seventeenth Quarterly Progress Report, January 1 - March 31, 1980.	
GEAP-NUREG-21304-18	BWR Blowdown/Emergency Core Cooling Eighteenth Quarterly Progress Report, April 1 - June 30, 1980.	
GEAP-NUREG-21304-19	BWR Blowdown/Emergency Core Cooling Nineteenth Quarterly Progress Report, July 1 - September 30, 1980.	
GEAP-NUREG-21304-20	BWR Blowdown/Emergency Core Cooling Twentieth Quarterly Progress Report, October 1 - December 31, 1980.	

B.2 PLANNED REPORTS FOR THE BD/ECC PROGRAM

The following table provides a list of reports planned as part of the BD/ECC Program. The reports for the BD/ECC1A phase are expected to be completed by the end of the second quarter of 1981. The report schedule for the FIST Program reports has not yet been determined.

Title	Principal Contents
BWR Blowdown/Emergency Core Cooling Program - 64 Rod Bundle Core Spray Interaction (BD/ECC1A) Final Report, Volume I, Large Break Tests	Results from large break testing.
BWR Blowdown/Emergency Core Cooling Program - 64 Rod Bundle Core Spray Interaction (BD/ECC1A) Final Report, Volume II, Small Break TEsts	Results from small break testing.
BWR Blowdown/Emergency Core Cooling Program - 64 Rod Bundle Core Spray Interaction (BD/ECC1A) Final Report, Volume III, Low-Flow Bundle Uncovery Tests	Results from boil-off testing.
FIST Test Plan	Preliminary plan and test strategy for FIST testing.
FIST Facility Description	Detailed description of FIST facility configuration.
FIST Final Report	Summary and conclusions from the FIST Program.

Report No./Type	Title/Author(s)	Principal Contents
GEAP-NUREG-21304-14	BWR Blowdown/Emergency Core Cooling Fourteenth Quarterly Progress Report, April 1 - June 30, 1979.	
GEAP-NUREG-21304-15	BWR Blowdown/Emergency Core Cooling Fifteenth Quarterly Progress Report, July 1 - September 30, 1979.	
GEAP-NUREG-21304-16	BWR Blowdown/Emergency Core Cooling Sixteenth Quarterly Progress Report, October 1 - December 31, 1979.	
GEAP-NUREG-21304-17	BWR Blowdown/Emergency Core Cooling Seventeenth Quarterly Progress Report, January 1 - March 31, 1980.	
GEAP-NUREG-21304-18	BWR Blowdown/Emergency Core Cooling Eighteenth Quarterly Progress Report, April 1 - June 30, 1980.	
GEAP-NUREG-21304-19	BWR Blowdown/Emergency Core Cooling Nineteenth Quarterly Progress Report, July 1 - September 30, 1980.	
GEAP-NUREG-21304-20	BWR Blowdown/Emergency Core Cooling Twentieth Quarterly Progress Report, October 1 - December 31, 1980.	

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BWR Blowdown/Emergency Core Cooling Program - 64 Rod Bundle Core Spray Interaction (BD/ECC1A) Final Report, Volume II, Small Break TEsts	Results from small break testing.
BWR Blowdown/Emergency Core Cooling Program - 64 Rod Bundle Core Spray Interaction (BD/ECC1A) Final Report, Volume III, Low-Flow Bundle Uncovery Tests	Results from boil-off testing.
FIST Test Plan	Preliminary plan and test strategy for FIST testing.
FIST Facility Description	Detailed description of FIST facility configuration.
FIST Final Report	Summary and conclusions from the FIST Program.

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