UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DEC 4 1981

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 127 "HEAT TRANSFER AND HYDRAULICS DURING A BWR LARGE-BREAK LOCA"

Reference: L. S. Lee et al., "BWR Large Break Simulation Tests - BWR Blowdown/Emergency Core Cooling Program," NUREG/CR-2229, March 1981.

127

This memorandum transmits the results of completed research investigating heat transfer and hydraulics during the blowdown and ECC injection phase of a boiling water reactor (BWR) large-break loss of coolant accident (LOCA). This research was conducted under the Blowdown/Emergency Core Cooling Program which is jointly sponsored by the U.S. Nuclear Regulatory Commission, the Electric Power Research Institute and the General Electric Company. The BWR Blowdown Heat Transfer Research Review Group reviewed the material in this Research Information Letter on September 18, 1981 and their comments are included in this summary.

Tests simulating the BWR large-break LOCA have been conducted in the Two-Loop Test Apparatus (TLTA), which is a scale model of a BWR utilizing a single full sized electrically simulated fuel bundle. These tests and analyses are reported in the referenced report. A summary of the results is enclosed.

The TLTA facility has identified a large degree of potential conservatism in the BWR evaluation model (EM). Key areas of conservatism identified include:

1. Delayed bundle draining due to a countercurrent flow limit (CCFL) at the side entry orifice (SEO) and a resulting delay in bundle heat-up and removal of stored energy,

2. Good cooling by steam and droplets during periods of essentially an empty bundle, and

3. Early bundle filling and quenching through the leakage paths.

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427-4260

In view of the large conservatism identified, it is expected that licensees will submit improved EM's that result in lower calculated peak clad temperature and thus more optimal plant operation (i.e., manage core to maximize fuel efficiency rather than minimize thermal limits). The Office of Research feels that some reduction in the overall conservatism is appropriate, especially if the new EM's are sufficiently improved so as to better describe the scenario.

The TLTA data is adequate for use in assessing both EM's and best estimate models. However, it should be recognized that the TLTA is a single channel facility. TLTA data should be used in conjunction with results from the 30° Steam Sector Test Facility (SSTF). SSTF results have shown significant multichannel and multidimensional phenomena. Most of these phenomena, such as enhanced ECC penetration in the bypass and in lower power bundles, appear beneficial. However, multichannel effects may reduce the benefit of SEO CCFL observed in the TLTA. Therefore, it is recommended that both integral data from the TLTA and separate effects data from SSTF be used in judging the adequacy of calculations.

We feel that the existing large-break LOCA data base is adequate for BWR's.

The TLTA is now being upgraded to better simulate small and intermediate-break LOCA's and non-LOCA transients. While a very limited number of large-break LOCA tests are planned for use in final BWR TRAC assessment, no new phenomena are expected and the emphasis of the program will not be large breaks. The SSTF testing is also complete and will be reported in FY 1982. The only planned future large-break LOCA research is the use of this data to assess the BWR TRAC code.

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Office of Nuclear Regulatory Research

Enclosure: TLTA Large-Break
LOCA Results

Enclosure

TLTA LARGE-BREAK LOCA RESULTS

W. D. Beckner

TLTA Large-Break LOCA Results

This paper summarizes the results of completed research investigating heat transfer and hydraulics during the blowdown and ECC injection phase of a boiling water reactor (BWR) large-break loss of coolant accident (LOCA). This research was conducted under the Blowdown/Emergency Core Cooling (BD/ECC) Program which is jointly sponsored by the Nuclear Regulatory Commission (NRC), the Electric Power Research Institute (EPRI) and the General Electric Company (GE). The BWR Blowdown Heat Transfer (BDHT) Research Review Group reviewed the material in this Research Information Letter (RIL) on September 18, 1981 and their comments are included in this summary.

1.0 Background

Tests simulating the BWR large-break LOCA have been conducted in the Two-Loop Test Apparatus (TLTA) which is a scale model of a BWR utilizing a single full sized electrically simulated fuel bundle. The TLTA was originally used to investigate heat transfer during the blowdown phase of the LOCA in a BWR/4 configuration with a 7x7 simulated fuel bundle (Reference 1). The TLTA was then systemmatically reconfigured to investigate blowdown heat transfer in a BWR/6 scaled system with an 8x8 simulated bundle as reported in Reference 2. The work transmitted herein represents the final evolution of planned large-break LOCA research in the TLTA. This research, reported in Reference 3, involves simulation of the BWR LOCA (BWR/6 with 8x8 fuel) through the ECC injection phase and early reflood. In order to correctly simulate the early LOCA blowdown in a scaled system, compromises had to be made which prevented testing of the entire LOCA. In particular, the jet pumps were not full height which prevented full bundle reflood. However, as indicated in the results, the temperature transient was terminated or the bundle completely quenched in these tests prior to bottom reflood and thus there was little need for continuation of the tests.

Two test series are reported. Configuration TLTA-5 simulated a BWR/6 with an 8x8 bundle. These tests utilized an ANS x 1.20 power decay up to 50 seconds. Beyond 50 seconds, the power was held constant and was thus too high. The power was held constant beyond 50 seconds because lower than expected rod temperatures allowed the tests to progress longer than expected. The TLTA-5 series, while atypical, should be useful for heat transfer coefficient evaluation because the higher power resulted in sustained high temperatures. The second test series, TLTA-5A configuration, utilized an ANS x 1.0 power decay curve throughout the tests and incorporated leakage paths between the simulated bypass region (area between fuel channels) and the bundle. This latter change reflects a design change in BWR's and resulted in significant changes in the system response.

2.0 Results

The results of these tests are summarized in Reference 3 along with data from major tests. This data is also available through the NRC Data Bank at INEL.

Peak rod temperatures observed in these tests with ECC injection were generally low (700-1100°F). Early temperature excursions due to CHF were only observed during the highest power tests and these initial temperature rises were quickly rewetted by high core flows as lower plenum fluid flashed and swelled through the bundle. Sustained heat-up was only observed after fluid drained from the bundle 30-40 seconds after the transient initiation. By this time the power level had decayed significantly and stored energy had been removed, thus limiting the heat-up rate. Even during this period when the bundle was essentially empty, ECC and residual upper plenum fluid periodically penetrated the bundle and quenched the rods sporadically. Figure 1 illustrates a selected number of the higher temperatures for three tests:

1. Average power with no ECC injection

2. Average power with average ECC injection

3. Peak power with low ECC injection

Figure 2 shows the corresponding heat transfer coefficients derived from these selected temperature traces. The heat transfer coefficient never drops below 10 Btu/Ft2-H-°F and periodically increases during rewets. Also shown for comparison are typical heat transfer coefficients used in licensing calculations which are shown to be highly conservative.

These tests could not be run through complete reflood because the short jet pumps prevented complete core covery by classical bottom reflood. However, tests in the 5A series exhibited significantly different behavior due to the leakage paths between the bottom of the fuel channel and the bypass region (area between fuel channels simulated by a pipe in the TLTA). In these tests, the bundle refilled completely and quenched the bundle prior to refilling of the lower plenum. ECC fluid injected in the bypass entered the bundle through the leakage paths and was prevented from draining to the lower plenum by CCFL at the side entry orifice (SEO).* This finding is even more significant in view of preliminary results from the 30° Sector Steam Test Facility (30° SSTF).

These tests have shown that multidimensional effects prevent flooding at the top of the bypass. Thus for plants without direct injection in the bypass (BWR/4), ECC fluid injected in the upper plenum can drain between the fuel channels and reflood the bundle from the bottom through the leakage paths.

Another interesting phenomena observed in these tests is that the rate of depressurization was slower with ECC injection. NRR has previously requested an explanation of this phenomena and an evaluation of our ability to calculate it. We now believe that this phenomena was caused by increased liquid at the break with ECC injection. Significant ECC fluid did reach the lower plenum during the blowdown phase. However, the lower plenum can only fill to the height of the jet pumps during the blowdown. Any liquid reaching the lower

*The SEO is the restriction at the bottom of the fuel channel used to control flow distribution.

plenum after it fills to the level of the jet pumps will be entrained up the jet pumps. Thus in the tests with ECC injection, some ECC fluid reached the break via the jet pumps and slowed the depressurization rate. Calculations of TLTA tests using BWR TRAC have not yet predicted this behavior due to problems in calculating the correct lower plenum mass. The reason for BWR TRAC's failure to correctly calculate the lower plenum mass has been identified and we are actively pursuing a solution.

3.0 Evaluation

The TLTA facility has identified a large degree of potential conservatism in the BWR evaluation model (EM). Key areas of conservatism identified include:

1. Delayed bundle draining due to CCFL at the SEO and a resulting delay in bundle heat-up and removal of stored energy,

2. Good cooling by steam and droplets during periods of essentially an empty bundle, and

3. Early bundle filling and quenching through the leakage paths.

In view of the large conservatism identified, it is expected that licensees will submit improved evaluation models (EM) that result in lower calculated peak clad temperature and thus more optimal plant operation (i.e. manage core to maximize fuel efficiency rather than minimize thermal limits). RES feels that some reduction in the overall conservatism is appropriate especially if the new EM's are sufficiently improved so as to better describe the LOCA scenario.

However, when using TLTA data to assess EM's, it should be recognized that the TLTA is a single channel facility. TLTA data should be used in conjunction with results from the SSTF. SSTF results have shown significant multi-channel and multidimensional phenomena. Most of these phenomena, such as enhanced ECC penetration in the bypass and in lower power bundles, appear beneficial. However, multi-channel effects may reduce the benefit of SEO CCFL observed in the TLTA. Therefore, it is recommended that both integral data from the TLTA and separate effects data from SSTF be used in judging the adequacy of EM calculations.

4.0 Future Research

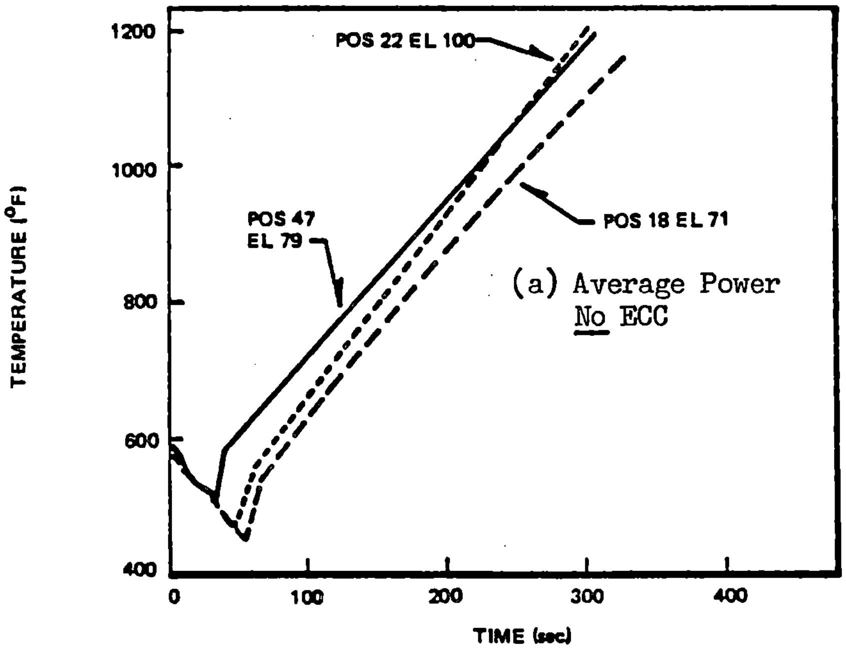
The TLTA is being upgraded to better simulate small and intermediate-break LOCA's and non-LOCA transients. While a very limited number of large break LOCA tests are planned for use in final BWR TRAC assessment, no new phenomena are expected and the emphasis of the program will not be large breaks. The SSTF testing is also complete and will be reported in FY 1982. The only planned future large-break LOCA research is the use of this data to assess the BWR TRAC code.

REFERENCES

1. R. Muralidharan et al, "BWR Blowdown Heat Transfer Final Report," GEAP-21214, February 1976.

2. W. S. Hwang et al, "BWR Blowdown/Emergency Core Cooling Program - 64-Rod Bundle Cooling Heat Transfer (8x8 BDHT) Final Report," GEAP-NUREG-23977, September 1978.

3. L. S. Lee et al, "BWR Large Break Simulation Tests - BWR Blowdown/Emergency Core Cooling Program," NUREG/CR-2229, March 1981.



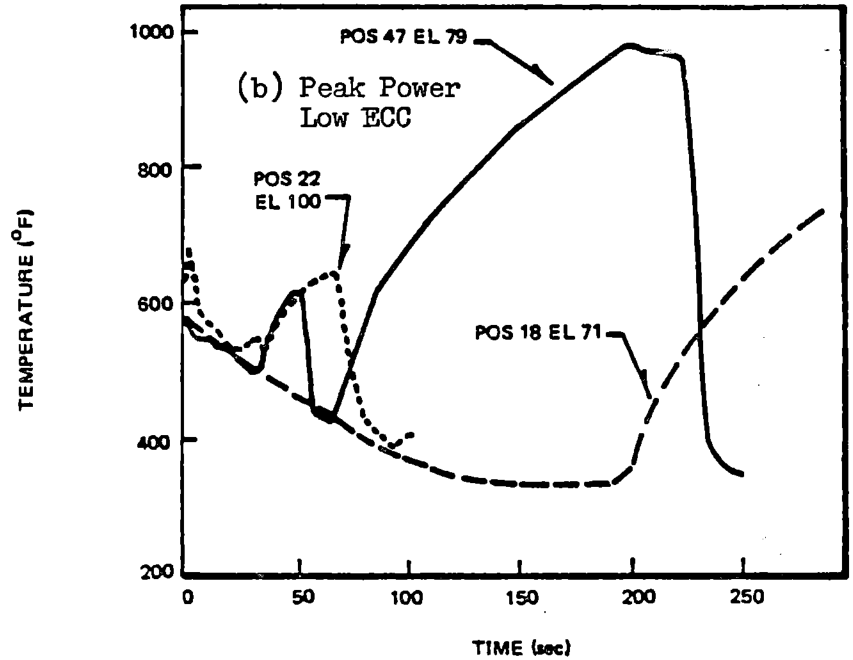
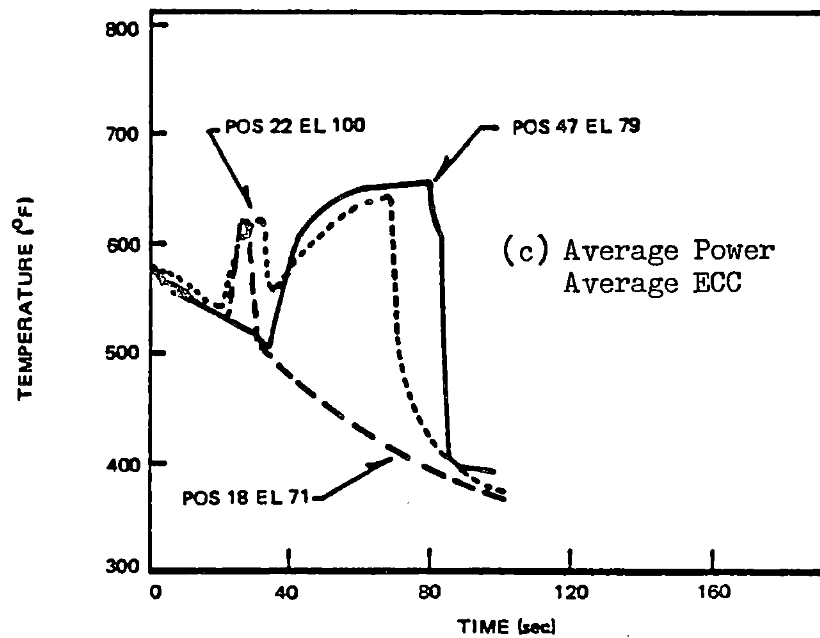
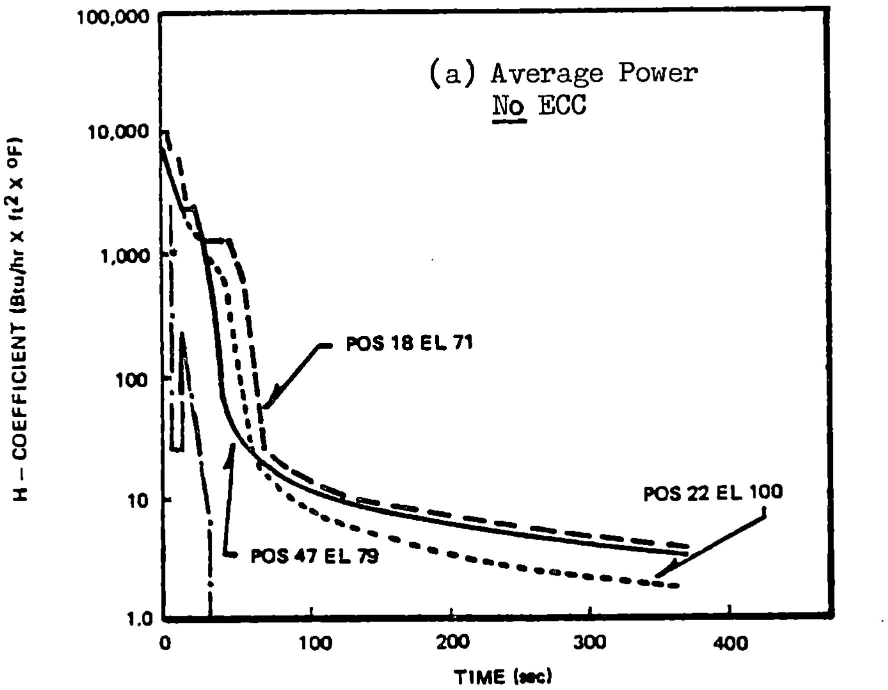
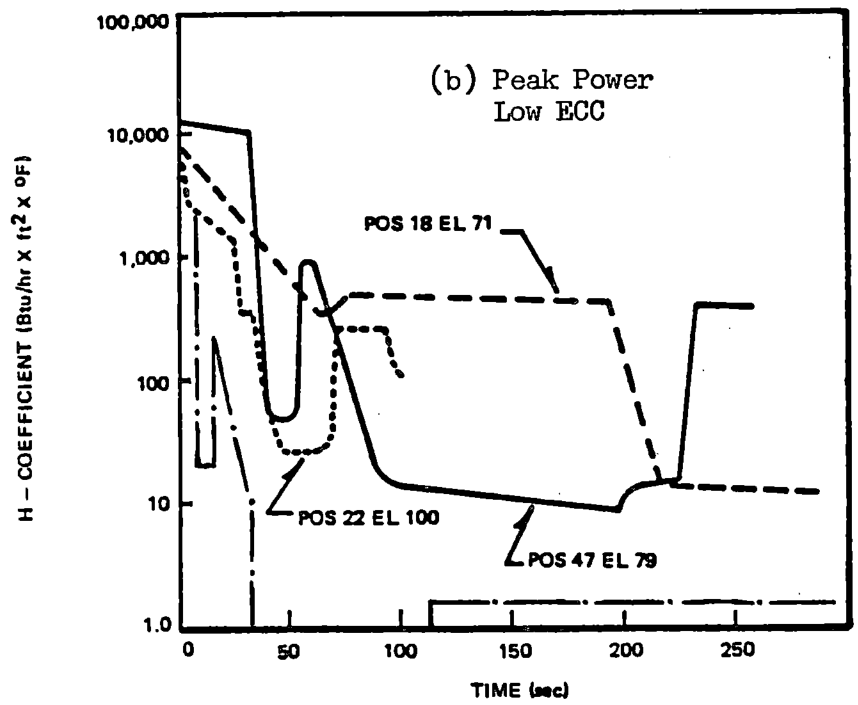


Figure 1 – Clad Temperatures From Typical TLTA Tests.







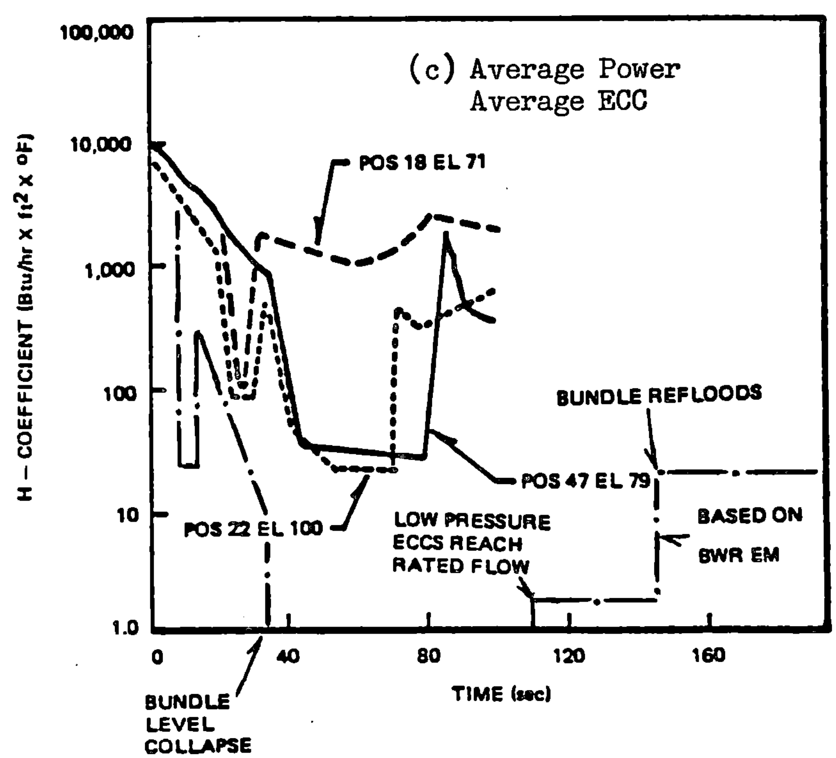


Figure 2 – Heat Transfer Coefficients From TLTA Tests Compared With EM Based Heat Transfer Coefficients.

SUMMARY

RESEARCH INFORMATION LETTER NO. 127

"HEAT TRANSFER AND HYDRAULICS DURING A BWR LARGE BREAK LOCA"

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Results of completed research investigating the BWR Large Break LOCA are summarized. This Research involved experimental simulations in the TLTA which is a full pressure, scale model of a BWR using a single electrically simulated fuel channel. These tests have identified a large degree of potential conservatism in the BWR Evaluation Model.

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G. Knighton

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Original signed by:
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Office of Nuclear Regulatory Research

Enclosure: TLTA Large-Break
LOCA Results

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*See Previous Concurrence

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