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

SEP 29 1978

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

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER - #37 LOFT REACTOR SAFETY PROGRAM RESEARCH RESULTS THROUGH OCTOBER 1, 1978

I.0 INTRODUCTION

This Research Information Letter transmits the significant results that have been obtained from the LOFT Reactor Safety Research Program through October 1, 1978.

Unique among research projects, LOFT is a complete pressurized water reactor (PWR) designed to operate at a power level of 55 MWt. The LOFT research program has been developed to provide experimental information relevant to the licensing criteria for large commercial PWR's. The major portion of this program is directed at an improved understanding of the loss-of-coolant accident (LOCA) and the performance of emergency core cooling systems using thermal-hydraulic, core physics, structural and fuel behavior data obtained through a series of loss-of-coolant experiments.

This letter is based on data obtained from the first series of experiments, L1, which was performed in the absence of nuclear power. In the final experiment of this series, L1-5, the core was in place, but in a shutdown condition. Consequently, the results derived from these investigations are applicable only to the thermal-hydraulic and structural phenomena associated with the LOCA with Emergency Core Cooling (ECC) injection.

The results are related to those of the Semiscale program and to LOCA behavior of commercial pressurized water reactors (LPWR's) through the scaling rationale used to scale Semiscale to LOFT and to scale LOFT to a LPWR.

This letter briefly describes the objectives of the LOFT program, the scaling design criteria and experimental conditions of the L1 series.

The experimental results are presented in terms of their evaluation of scaling rationale and their comparison with predictions of analytical models. Finally, the forthcoming nuclear experimental program is described together with a statement of how the nuclear program is expected to extend the conclusions presented in this letter.

2.0 SUMMARY

In general, the results support the conservative intent of those portions of the evaluation model requirements contained in the licensing criteria which were investigated in the L1 series. In particular, the time delay in the delivery of emergency core coolant to the lower plenum due to the effect of contact with the hot metal surfaces (the hot wall effect) was found to be small (0.5 to 1.0 s). Based on the relative surface area to volume ratio of the downcomer, the hot wall effect in a LPWR should be less than in LOFT.

Also, for a loss-of-coolant experiment in the absence of nuclear power generation, the L1 results indicated that:

- the lower plenum does not completely void before actuation of the accumulators,
- the emergency core coolant bypass is less than 30%, and
- mixing of emergency core coolant with primary system coolant does not cause violent pressure oscillations which could effect structural loading and fluid behavior in the system.

In addition, several advances in best-estimate modeling were made in the areas of the reactor vessel downcomer and the pressurizer as a result of the experimental data acquired:

- multi-dimensional or asymmetric fluid flow was observed in the downcomer,
- incomplete mixing of emergency coolant was measured, with a resultant subcooling in the lower plenum coolant of up to 50 K, and
- accurate modeling of the pressurizer surge line flow during the first 10 seconds of saturated blowdown is important in the prediction of the primary coolant system fluid conditions.

The results and conclusions presented herein are considered applicable to

10 CFR 50.46, subsections (a) (1), (b) (4), (c) and to Appendix K, parts 1-a-1, 6, 7, 1-c-1, 2, 3, 6, and 7. Review and evaluation of these paragraphs in the light of the thermal-hydraulic phenomena observed in LOFT should aid in the evaluation of LPWR safety. Subsequent LOFT test series will provide information regarding the effect of nuclear and decay heat generation on the above phenomena and on LOCA-ECCS behavior during reflood.

3.0 BACKGROUND

3.1 Scaling Rationale

The primary system, reactor system, and emergency core cooling system (ECCS) of the Loss-of-Fluid Test (LOFT) facility (1,2) are designed to 'scale' significant features of a four-loop LPWR and to reproducibly simulate typical system transient response to a LOCA. The scaling rationale (3) applied in LOFT makes extensive use of principles that have been applied in a wide range of experiments within and beyond the nuclear power industry. The general scaling rules applied in LOFT are as follows:

Fuel linear heat generation rate is full scale. Nuclear fuel design is identical to commercial reactor fuel except for length (1.7m);

Core power is taken as the basis for scaling of component volumes, that is,

$$\text{LOFT Volume} = \frac{\text{LOFT Power}}{\text{LPWR Power}} \times \text{LPWR Volume};$$

Flow areas (excepting break and core) are scaled to provide identical mass fluxes;

The break area-to-actual system volume ratio is set identical to the LPWR value under study;

Initial conditions (pressure, temperature, mass flux) are set identical to the LPWR values.

Assessment of the scaling rationale is accomplished by comparison of LOFT experimental results with results of counterpart experiments conducted at the Semiscale facility. Semiscale (4) is a scale model of LOFT that uses the same scaling rationale and about the same scale ratios as were used in scaling LOFT to the LPWR. Table I summarizes some major scaling parameters for LOFT, Semiscale, and the LPWR.

3.2 LOFT Program Objectives

The specific LOFT Program Objectives are:

1. Provide integral system experimental data to the U.S. Nuclear Regulatory Commission (NRC) and the nuclear industry for the assessment and development of analytical methods used to predict:

   The transient thermal-hydraulic, mechanical, and nuclear response of the reactor system and primary system components under LOCA conditions.

   The capability of current ECCS designs to fulfill their intended function.

   The margin of conservatism inherent in the capability of current ECCS designs.

   The effectiveness of alternate ECCS concepts.

2. Investigate thresholds or unexpected phenomena that could affect the validity of the analytical models used to predict the thermal-hydraulic mechanical, and nuclear response of the reactor system.

Although a LOFT loss-of-coolant experiment (LOCE) cannot be made to exactly duplicate a LPWR LOCA, the LOFT design and performance of the LOCE ensure that all the significant phenomena occur in about the same magnitude and time sequence. The experimental results together with those from separate effects and other integral effects experiments can be used to evaluate the scaling rationale and the analytical models used in LOCA codes.

3.3 The L1 (Nonnuclear) Series

The research results reported in this letter were obtained from the first series (5) of LOCE's conducted in the LOFT facility. These LOCE's were nonnuclear in nature (no nuclear core heat) and were intended to provide thermal-hydraulic information during blowdown and core refill, and structural information resulting from variations in principal parameters associated with break size and location, ECCS injection, and primary system component operation. The first five of the six LOCE's in this series contained a mechanical simulation of the core for proper operating loop pressure drop simulation. The last experiment contained the LOFT nuclear core in a shutdown condition but with the control rods withdrawn. A summary of the system configuration and actual initial conditions for the six LOCE's is given in Table II. (Note that the L1-4 experiment was both a U.S. and International Standard Problem).

Concurrent with the experimental program, supporting analysis provided pre-experiment prediction and post experiment analysis for the purpose of developing and refining code models and identifying areas for additional code development. Thermal-hydraulic analysis was carried out principally with the RELAP4 (6,7) code series, ending with RELAP4/MOD6 (8). The fuel pin thermal-mechanical response prediction for the last LOCE in the series was done with the FRAPT4 (9) code. Subcooled blowdown and system structural response analyses were carried out with the WHAM6 (10), SAP (11), and SHOCK (12) codes.

The experimental data (13, 14, 15, 16, 17, 18) obtained from the experiments provided the required information to fulfill the objectives (5) of this first part of the LOFT program. Measurement systems operated at an average survival rate of 94%. The redundancy designed into the instrument and data acquisition system was usually sufficient to compensate for the 6% failure rate.

In general, the uncertainties in the measured principal variables were as follows:

temperature	± 3 K	1.0%
pressure	∓ 0.03 MPa	2.2%
differential pressure	∓ 0.01 MPa	0.2%
density	∓ 0.03 Mg/m3	3.75%
momentum flux	∓ 12.0 Mg/m.s2	20.0%
velocity	± 2.7 m/s	13.5%

Techniques and instruments are well developed for measurements of the first four variables and consequently these measurements are relatively accurate. However, as indicated in the above table, the last two variables, momentum flux and velocity, are difficult to measure in two-phase flow conditions. The uncertainties stated for these variables reflect this difficulty and represent the largest uncertainties which occur during low quality fluid conditions (37).

Within the listed uncertainties, the experimental data were consistent during each individual experiment. Also, the experimental data among all the experiments were repeatable in those time regions of the loss-of-coolant transients where repeatability was expected.

4.0 RESULTS

Two fundamental aspects of the LOFT program objectives are used as the framework for this discussion. They were the evaluation of the scaling rationale and of the analytical models intended for LPWR application. Generic results from LOFT and Semiscale are presented in relation to LPWRs through the scaling rationale, while results specific to LOFT are presented primarily in relation to the analytical models for LPWR application.

4.1 Assessment of the Scaling Rationale

4.1.1 Surface to Volume Ratio and Operating Loop Resistance

The scaling rationale leads to distortion of the surface area-to-volume ratio. Increased values of this ratio, as scaled systems are made smaller, affects the primary loop resistance which in turn may affect the thermal-hydraulics of the loss-of-coolant transient. Analysis of Semiscale and LOFT experiments (19) and theoretical analyses using RELAP4/MOD5 (19), FRAP-T2 (20), and FLOOD4 (21) computer codes have shown that variations in operating loop resistance have no significant effect on the thermal-hydraulics in loss-of-coolant transients. The trend of the Semiscale and LOFT experimental data is toward independence of the effects of the area-to-volume ratio and of the operating loop resistance on thermal-hydraulic phenomena in LPWR's.

4.1.2 Hot-Wall Delay

Another effect of increased surface area-to-volume ratio is to increase the relative heat transfer from the walls to the fluid. This can cause delay in the delivery of ECC to the lower plenum (assuming cold leg ECC injection) through the mechanism of steam generation and counter-current flow. The hot wall induced delay in ECC delivery follows this dependency on the surface area-to-volume ratio in LOFT and Semiscale experiments. The Semiscale hot wall delay is approximately 10 s (22) whereas in LOFT the hot wall delay is in the range of 0.5 to 1.0 s (23). The hot wall delay range in LOFT applies for conditions at ECC injection time ranging from 0.34 MPa, 555 K wall temperature (14), to 4.14 MPa, 520 K wall temperature (17, 18). The ECC hot wall delay effect in a LPWR is considered to be less than that in the LOFT geometry and thus, as in

LOFT, does not represent a significant deterrent to the intended operation of ECCS designs. (24)

4.1.3 ECC Flow Asymmetry in the Downcomer

The experimental data from the LOFT experiments indicate flow asymmetry in the downcomer which persists essentially throughout the transient and involves both original primary coolant system (PCS) fluid and ECCS fluid. Direct comparison of LOFT and Semiscale results in this area is complicated by different measurement systems necessitated by hardware constraints. Semiscale counterpart experiment data indicate that downcomer flow behavior is different from that in LOFT in that there is no evidence of asymmetric flow behavior. The scaling rationale for the two experimental systems kept the active core length the same while scaling the coolant volumes. Thus, the downcomer in Semiscale is more one-dimensional than the LOFT downcomer as indicated by the ratio of length-to-diameter (24.11 for Semiscale and 4.53 for LOFT) of the two downcomers. The trend is toward asymmetric flow behavior as this ratio decreases. Such asymmetric flow behavior should therefore be expected in LPWR downcomers (L/D approximately 1.3) and provision for multidirectional flow in the downcomer should be included in analytical models (refer to the following section for analytical model comparisons with LOFT experimental data).

4.1.4 ECC Bypass

ECC bypass occurs in both LOFT and Semiscale for cold leg ECC injection. Approximately 30% of the ECC is bypassed out the break in LOFT (25) by the time the accumulator empties. An additional 15% of the ECC is stored in the piping at this time. After the accumulator empties the refill rate is essentially equal to the pumped ECC injection rate. Once the pressure vessel is filled to the pipe break elevation the flow out of the break equals the pumped ECC injection rate. The percentage of ECC bypassed in Semiscale is larger than in LOFT. The difference is attributed to the different downcomer fluid behavior previously discussed. The implication is that, since the LPWR downcomer fluid behavior is considered to be similar to that in LOFT, the ECC bypass fraction in LPWR's at the time the accumulator empties will be less than (or no greater than) that in LOFT (30%).

4.1.5 ECC Mixing with Primary Coolant

Mixing of the injected cool ECC water with the hot PCS coolant has been of concern in LOCA analysis for several reasons. There has been some concern that the mixing process would be violent (26), causing substantial dynamic loads and affecting the fluid behavior in the downcomer and core by producing oscillatory flow. The rate of mixing influences the system depressurization and can influence condensing steam flows, thereby affecting downcomer bypass. Furthermore, the temperature of the fluid available for core cooling is influenced by the ECC fluid mixing process and this could therefore affect the progress of the reflood phase.

No evidence was found of violent pressure oscillations associated with the ECC fluid mixing process (25). Strain and acceleration data show no evidence of structural loading at the injection location. Some low amplitude pressure fluctuations were observed during the time of similar fluctuations in flow and temperature, but they did not produce significant dynamic loads on the system. The fluctuations in flow and temperature data were caused by incomplete mixing of ECC and PCS fluid. While these fluctuations do not significantly affect bypass, the fluctuations are indicative of the presence of subcooled fluid and its potential to influence the temperature of the coolant available for core cooling. The coolant temperature in the LOFT experiments has been shown to be as much as 50 K below saturation temperature (determined from measured pressure) near the bottom of the downcomer. This 50 K temperature difference can be assumed to be near the limit for LPWR's because the flow path from the ECC injection location in the cold leg piping to the lower plenum is somewhat longer in LPWR's than in LOFT, thus providing some additional time for ECC-PCS fluid mixing.

4.1.6 Lower Plenum Voiding

Lower plenum voiding during the initial system depressurization and prior to actuation of the ECCS accumulators is important in determining the time to refill the lower plenum (or to initiate core reflood). Both LOFT and Semiscale experiments (24) reveal incomplete voiding of the lower plenum. Incomplete voiding of the lower plenum occurred in all of the LOFT LOCE's. This result is significant since the LOCE's included variations in break size and location, core simulator-nuclear core configurations, and primary coolant pump operation. Comparisons of LOFT and Semiscale lower plenum voiding showed that more voiding generally occurred in the Semiscale geometry. This is attributed to symmetric fluid behavior in the downcomer and to the excessive lower plenum wall heat in Semiscale. The implication of the LOFT and Semiscale information at this time is that lower plenum voiding in LPWR's also will be incomplete at the time of accumulator initiation because of the similarity of downcomer fluid behavior expected in LPWR's and in LOFT.

4.1.7 Accumulator Nitrogen (N2) Expansion

The ECC delivery rate of the accummulator is dependent on the driving pressure of the N2 gas volume in the accumulator. Analysis (27) of the pressure-temperature transient of the N2 gas in the LOFT accumulator has shown that the N2 gas expands nearly isentropically. The Semiscale accumulator gas expansion is approximately midway between isothermal and isentropic. It is recommended that sensitivity studies continue to be required to obtain the proper accumulator gas expansion coefficient for the individual plant design.

4.1.8 Powered or Unpowered Primary Coolant Pump

The characteristics of the ECC penetration into the downcomer from the cold leg injection location shows a dependency on the primary coolant pump (PCP) operation. Comparison of the case where the PCP's were powered only up to the break initiation with the case where the PCP's were powered for the first 70 s after break initiation shows marked differences in downcomer ECC distribution as a function of time. Continued PCP power operation appears to impart additional momentum to the ECC which causes more circumferential migration of the ECC in the downcomer (increased multi-directional flow). This effect does not result in any significant differences in ECC delivery time to the lower plenum, in ECC bypass or in the amount of ECC stored in the cold leg piping after the accumulator empties (the PCP's were powered for only a few seconds beyond the time at which the accumulator empties). These differences of ECC penetration and distribution in the downcomer are not evident in Semiscale because of the one-dimensional behavior of the fluid in the Semiscale downcomer.

4.1.9 The Pressure Suppression System as a Model for the BWR Mark I and Mark II Systems

LOFT employs a pressure suppression system (PSS) (1,2) which has many of the significant features of BWR Mark I and Mark II systems. It is instrumented to provide information for analysis of thermal-hydraulic phenomena, structural loading and structural response. An analysis of the LOFT experiments (28) has shown that wet well vertical loading is strongly dependent on several parameters which are geometric and physical in nature. The geometric parameters include vent submergence in the wet well pool and the internal submergence level of the vents, referred to as pre-clearing.

The significant physical parameters include the energy integral, the energy input rate to the wet well, the rate of change of vent pressure and the non-synchronization of pressures in parallel vents. The total energy input and the input rate appear to have strong and possibly nonlinear effects; differences in the rate of change of vent pressure caused vertical loading differences of up to 30%; and the nonsynchronous pressures in parallel vents of the LOFT PSS caused venting to the pool to be non-synchronous. This behavior significantly reduced the magnitude of the expected vertical loads and, to the same end, could be designed into BWR suppression systems. For example, alternate vents could be different in length and consequently in submergence in the wet well pool.

Although the results of the LOFT PSS data cannot be extrapolated directly to other PSS geometries, the parameter dependencies found in the LOFT PSS should occur in other similar PSS geometries. The LOFT data therefore provide a good reference for analytical model development and verification.

4.1.10 Conclusions Regarding the Scaling Rationale

The LOFT LOCE's and the Semiscale counterpart experiments are, in general, in very good agreement (24, 29) and as a result support the scaling rationale used for research into integrated effects. Where differences are expected or have the potential of occurring because of the scaling rationale, the differences are in the directions expected. As a result of the scaling rationale, trends or bounds on several important parameters and phenomena have been identified.

4.2 Analytical Model Comparisons with LOFT Data

The analytical model research conducted concurrently with the experimental program resulted in several advances in modeling techniques to account for the thermal-hydraulic phenomena observed in the LOFT LOCE's. The pre-experiment predictions (30, 31, 32, 33, 34) were based on comparative analyses of the predictions and experimental data from previous experiments and, where possible, on post-experimental model analysis and development (35, 36). The knowledge gained from the L1 results has resulted in more accurate modeling techniques for the LOFT system, as discussed below.

4.2.1 Primary Coolant Pump Model

RELAP4 calculations are in good agreement with experimental results in those areas where one-dimensional, homogeneous equilibrium assumptions are valid. One such area is that of the primary coolant pump differential pressure. The Semiscale pump degraduation model was used in RELAP4 to predict the LOFT pump differential pressure quite well even though the LOFT pumps are different in size and design and the model did not predict the LOFT pump speed well. Although study of this situation continues, it may be that the pump model is unimportant in the prediction of the pump flow and the Semiscale model may be satisfactory for predicting the LPWR pump flow.

4.2.2 Downcomer Model

An area where one-dimensional, homogeneous equilibrium assumptions are not valid is the reactor vessel downcomer: models which employ one set of vertically stacked volumes assigned to the downcomer do not provide results that are in as good agreement with LOFT LOCE data as do models with more than one set of vertically stacked volumes assigned to the downcomer. Multidimensional or asymmetric flow as evidenced in the LOCE data can be predicted only by dividing the downcomer volume circumferentially as well as vertically. One dimensional downcomer modeling leads to overprediction of ECC bypass and lower plenum voiding. This type of downcomer modeling is conservative and is in keeping with the intent of evaluation models; however, best-estimate models should include the multi-dimensionality of the fluid behavior in the downcomer.

4.2.3 Mixed Fluid Model

The experimental evidence of non-homogeneous flow and incomplete ECC mixing invalidates the assumption of instantaneous complete mixing in the RELAP4 code. The difference between the code assumption and the data is observable in the system pressure which is lower during ECC injection in the code prediction than in the experiments. Instantaneous or rapid mixing will lower the pressure in the PCS and could cause a higher influx of accumulator coolant. Also, the temperature of the ECC fluid in the lower plenum will remain at saturation and not be subcooled as observed in the experiments. A non-instantaneous mixing model is being incorporated into RELAP4 and should account for the incomplete ECC-PCS fluid mixing observed in the LOFT experiments. Evaluation performed with this model change will have to be done to determine whether or not the instantaneous mixing model is conservative for the entire accident period.

4.2.4 Pressurizer Model

The RELAP4 pressurizer model markedly affects the pressurizer discharge flow and thus the primary system pressures, flows and densities during the first 10 seconds of the transient. This is because the pressurizer liquid is initially at the saturation temperature of the primary system pressure, and therefore represents a significant source of high-temperature fluid. Thus the rate and direction of the flow from the pressurizer as it enters the intact loop hot leg is important for predicting the early portion of saturated blowdown (36).

Consequently, pressurizer modeling must include all the important pressure loss phenomena in the pressurizer surge line. Two-phase multipliers, friction losses, modeling of the form losses in the bends in the pressurizer surge line, and vena-contracta effects at the choke point are important considerations (36).

4.2.5 Breakflow Model

Parametric studies with RELAP4 have demonstrated the expected sensitivity of the calculations to critical flow model parameters. Whereas the uncertainty in the measured breakflow is too large in the LOFT experiments to be used in the assessment of the breakflow models, comparisons of indirectly influenced variables such as system pressure and flow densities have shown that fairly successful modeling of the breakflow was achieved. For the L1 series, in which offset shear breaks were simulated, the breakflow model consisted of the HF-HEM critical flow model with a 2% transition quality, a 0.848 contraction coefficient at the broken loop cold leg break, and a 1.0 contraction coefficient at the broken loop hot leg break.

4.2.6 Subcooled Blowdown Model and Structural Loads

Subcooled blowdown was well predicted by the WHAM6 code and it has been shown that the significant modeling parameters - those concerning the time step, the attenuation and dispersion of acoustic pressure waves, and component modeling - were accurately determined (37). A sensitivity study of these parameters is in progress. Since the acoustic phenomena controlling subcooled blowdown are linear in nature, the results of the sensitivity study can be scaled to a LPWR.

The predictions by the WHAM6 code of pressure throughout the PCS during single phase or subcooled blowdown are used as forcing functions for structural response code models. LOFT has been designed and constructed using WHAM6 predictions with a zero loss factor for conservatism, a worst case LOCA break condition, and standard seismic criteria. Analysis of PCS acceleration and strain data (38) and fuel assembly displacement data have shown that, within the conservatism of PWR design and construction standards criteria, the structural systems of LOFT and of the LOFT core have large safety factors for handling structural loads caused by loss-of-coolant accidents. Such design and construction standards criteria and accident assumptions applied to LPWR's are expected to result in a structurally sound system in the event of a LOCA.

4.2.7 Conclusions Regarding Current Analytical Models

Current models generally result in conservative predictions. Significant conservatism and modeling improvements have been identified in the one-dimensional downcomer, the instantaneous mixing in the vicinity of the injection points of the pressurizer fluid and the ECC, and the modeling of structural loadings, while relatively accurate modeling has been achieved in estimating the primary coolant pump flow and the breakflow.

5.0 Recommendations

The results of the LOFT L1 series above are recommended for use by NRR in its interpretation and application of LOCA ECCS evaluation model criteria and related codes. Although the data are limited to nonnuclear blowdown conditions, the predictions to which data comparisons have been made have assumed appropriate initial conditions and therefore the conclusions are believed to be valid.

6.0 Future Program

The effect that nuclear power generation will have on the conclusions of this RIL is soon to be studied in the L2 power ascension series described in Table III. This is to be a series of full-size double-ended cold leg breaks initiated at increasing power levels with cold-leg ECC injection and with variations in assumptions regarding off-site power supply and in fuel prepressurization.

7.0 Coordination Contact

For coordination of any further evaluation of these results and for discussion and future experiments the reader is advised to contact Dr. G. Donald McPherson LOFT Program Manager, RES, Telephone 427-4437.

Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosures:
1. Table I LOFT-Semiscale-LPWR Scaling Parameters
2. Table II L1 LOCE Series System Configurations and Initial Conditions
3. Table III L2 Series - Power Ascension Series

TABLE I

LOFT - SEMISCALE - LPWR SCALING PARAMETERS

	Semiscale	LOFT	LPWR
Volumes			
Total PCS (m^3)	0.23	7.22	347
Reactor Vessel (% of PCS)	37	34	38
Intact Loop (% of PCS)	44	48	51
Broken Loop (% of PCS)	19	18	11
Power (MW)	1.6	55	3400
Length of Active Core (m)	1.67 and 3.66	1.67	3.66
Ratios			
Volume/Power (m^3/MW)	0.14	0.13	0.10
Break Area/PCS Volume (m^{-1})	0.22	0.22	0.22
PWR Volume/Volume	1530	48	1

TABLE II

L1 LOCE SERIES SYSTEM CONFIGURATIONS AND INITIAL CONDITIONS

CONFIGURATION	L1-1	L1-2	L1-3	L1-3A	L1-4	L1-5
Pipe Break						
Location	Hot Leg	Cold Leg	Cold Leg	Cold Leg	Cold Leg	Cold Leg
Size	100%	200%	200%	200%	200%	200%
Opening Time, ms	17	17	17	18	18	19.5
Core	Simulator For ΔP	Simulator For ΔP	Simulator For ΔP	Simulator For ΔP	Simulator For ΔP	Nuclear Core
Primary System Pump Operation	Powered to T_o + 30 s	Power Terminated at T_o +< 1 s	Power Terminated at T_o +< 1 s	Power Terminated at T_o +< 1 s	Power Terminated at T_o +< 1 s	Powered to T_o + 70 s
Broken Loop						
Pump	Locked Rotor	Locked Rotor	Locked Rotor	Locked Rotor	Locked Rotor	Operating Pump
Simulator*	K = 25.65	K = 20.70	K = 20.70	K = 20.70	K = 20.70	K = 9.95
Intact Loop Resistance	Low Resistance K = 131.7	High Resistance K = 359.8	Low Resistance K = 131.7	Low Resistance K = 131.7	Low Resistance K = 131.7	Low Resistance K = 131.7
ECC Systems	HPIS, LPIS Accumulator	HPIS, LPIS Accumulator	HPIS, LPIS	HPIS, LPIS Accumulator	HPIS, LPIS Accumulator	HPIS, LPIS Accumulator
ECC Injection Location	Intact Loop Cold Leg	Intact Loop Cold Leg	Lower Plenum	Lower Plenum	Intact Loop Cold Leg	Intact Loop Cold Leg
ECC Systems Acutation Mode			Inadvertently			
Accumulator	Pressure	Time	Not Actuated	Pressure	Pressure	Pressure
LPIS	Pressure	Time	Time	Time	Time	Pressure-Level
HPIS	Time	Deliberately Not Actuated	Time	Time	Time	Pressure-Level
Secondary Coolant System	PCS Saturation Conditions, no Flow	PCS Saturation Conditions, no Flow	PCS Saturation Conditions, no Flow	PCS Saturation Conditions, no Flow	PCS Saturation Conditions, no Flow	PCS Saturation Conditions, no Flow
Initial Conditions	L1-1	L1-2	L1-3	L1-3A	L1-4	L1-5
Primary System						
Pressure, MPA	9.11	15.55	15.55	15.46	15.65	15.45
Temperature, K	555.4	555.4	555.2	556.5	552.15	555
Mass Flow, kg/s	301.13	284.76	294.84	280.98	268.4	176.1
Boration, PPM	0	0	0	0	1494	3087
ECCS Accumulator						
Pressure, MPA	4.07	3.87	Not Actuated	4.05	4.14	4.17
Temperature, K	312.04	308.99		311.48	306.15	304
Boration, PPM	0	0		0	3307	3155
Injected Volume, m^3	2.08	2.28		2.54	2.05	1.73
Gas Volume, m^3	1.35	1.28		1.13	1.16	0.97

*Darcy K factor based on 0.016 m^2 flow area.

TABLE III

L2 SERIES-POWER ASCENSION SERIES (WITH ADDED ALTERNATE ECCS TEST L4-1)

TEST NO.	POWER LEVEL (W/cm^2)	PCS FLOW/ΔT (kg/s)/(°C)	PRE-PRESSURIZED	PRIMARY COOLANT PUMPS	ECC DELAY
L2-2	78	171.4/23.9	NO	ON	NO
L4-1*	78	171.4/23.9	NO	ON	NO
L2-3	117	171.4/35.8	NO	ON	NO
L2-5	117	171.4/35.8	NO	OFF/ LOCKED	YES
L2-4	156	228.1/35.8	NO	ON	NO
L2-6	117	171.4/35.8	YES	ON	NO

All 200% Decl Breaks

All Assume Loss of One LPIS and HPIS Train

All L2 Series Tests Use Cold Leg ECC Injection

*L4-1, First of Alternate ECCS Using Lower Plenum Injection.

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5.0 Recommendations

The results of the LOFT L1 series above are recommended for use by NRR in its interpretation and application of LOCA ECCS evaluation model criteria and related codes. Although the data are limited to nonnuclear blowdown conditions, the predictions to which data comparisons have been made have assumed appropriate initial conditions and therefore the conclusions are believed to be valid.

6.0 Future Program

The effect that nuclear power generation will have on the conclusions of this RIL is soon to be studied in the L2 power ascension series described in Table III. This is to be a series of full-size double-ended cold leg breaks initiated at increasing power levels with cold-leg ECC injection and with variations in assumptions regarding off-site power supply and in fuel prepressurization.

7.0 Coordination Contact

For coordination of any further evaluation of these results and for discussion and future experiments the reader is advised to contact Dr. G. Donald McPherson LOFT Program Manager, RES, Telephone 427-4437.

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosures:
1. Table I LOFT-Semiscale-LPWR Scaling Parameters
2. Table II L1 LOCE Series System Configurations and Initial Conditions
3. Table III L2 Series - Power Ascension Series

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