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OVERVIEW OF THE LOFT EXPERIMENTAL PROGRAM

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ABSTRACT

The Loss-of Fluid Test (LOFT) facility, operated by EG&G Idaho, Inc., for the U.S. Nuclear Regulatory Commission, is designed as an integral test facility to study the behavior of commercial pressurized water reactors (PWRs) during a loss-of-coolant accident (LOCA). For this mission, six nuclear and one nonnuclear test series have been proposed to provide data on PWR transient behavior, but plans must be recognized as tentative and subject to change for a number of reasons.

The Nonnuclear Test Series, completed in April 1978, consisted of six loss-of-coolant experiments (LOCEs) performed with isothermal primary coolant temperatures. The Power Ascension Test Series, Series L2, proposes five LOCEs, simulating double-ended cold leg breaks (DECLB), to provide a controlled power escalation to a peak power of 52.49 kW/m. The Small and Intermediate Breaks Test Series, Series L3, will consist of three LOCEs designed to study the effects of smaller primary coolant system ruptures. These tests will be initiated by cold leg ruptures ranging from scaled 6.4-cm pipe ruptures to scaled 0.05-m^2 pipe cracks. Five LOCEs are proposed for the Alternate Emergency Core Cooling Systems (ECCS) Test Series, designated Series L4. These DECLBs will be used to study systems such as lower plenum emergency core coolant injection, hot leg injection, and combined hot and cold leg injection. Also included in the L4 series is a test involving upper plenum-downcomer pressure equalization valves. The Hot Leg Rupture Test Series, Series L5, will study PWR behavior during a double-ended hot leg rupture. Two LOCEs are currently proposed for

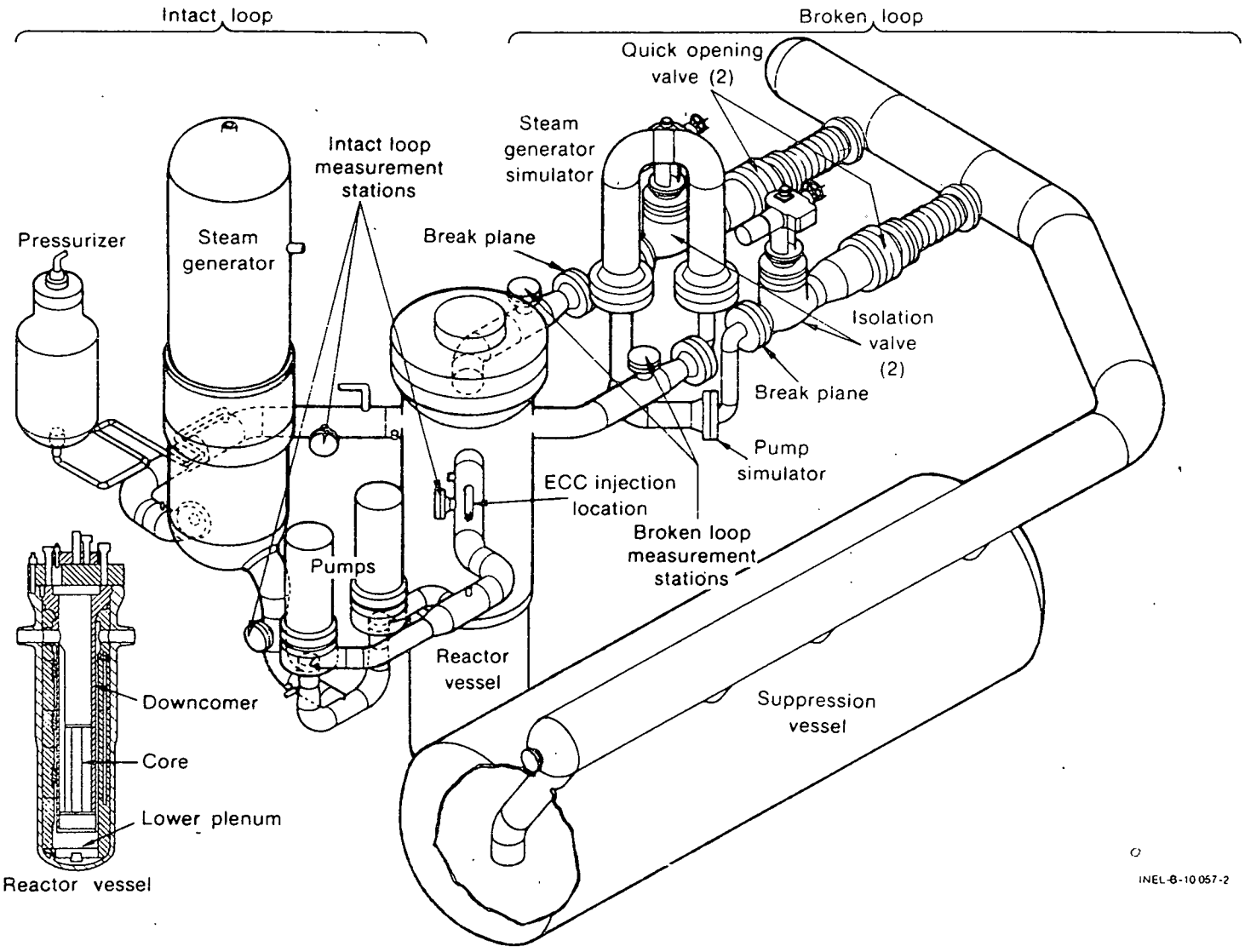

Fig. 1 Major components in the LOFT system.

extensive data acquisition and processing system is used to record experimental results from the instrumentation used in the facility.

To meet the LOFT Program objectives, seven test series, six nuclear and one nonnuclear, have been proposed and planned. These plans should be recognized as being tentative and subject to change due to any number of reasons, such as previous test results or industry events.

NONNUCLEAR TEST SERIES (SERIES L1)

The nonnuclear test series, completed between March 1976 and April 1978, consisted of six loss-of-coolant experiments. The experiments were performed with isothermal primary coolant temperature conditions. Heat was supplied from mechanical energy losses within the loop coolant pumps. The first five tests used a core simulator in place of a nuclear fueled core. The simulator was designed to represent only the flow resistance of a nuclear core. The final experiment (LOCE L1-5) was performed with the core installed but not generating nuclear heat. Table I provides a summary of the Nonnuclear Test Series and the parameters involved.

The objectives of this initial series were to checkout the LOFT facility, to demonstrate experiment control and reproducibility, to explore subcooled and saturated blowdown phenomena, and to provide data for the assessment of computer codes used in determining the safety of nuclear reactors. The results of this series met the objectives quite successfully.

POWER ASCENSION TEST SERIES (SERIES L2)

The Power Ascension Test Series proposes five LOCEs simulating double-ended cold leg (DECL) ruptures at a series of power levels from 26.3 to 52.5 kW/m. The primary objective of the L2 series is to progress from low and intermediate power LOCEs to a full power DECL LOCE as soon as possible without jeopardizing the integrity of the

TABLE I

SUMMARY OF PARAMETERS FOR NONNUCLEAR TEST SERIES

LOCE	Break Size	Break Type	Break Opening Time (ms)	Primary Coolant System Resistance	Emergency Core Coolant Injection Point	Primary Coolant System Pressure (MPa)
L1-1	100% break[a]	Hot leg	17.5[b]	Low	Cold leg	9.44
L1-2[c]	200% break[d]	Cold leg	50 ± 10[e]	High	Cold leg	15.45
L1-3	200% break[d]	Cold leg	17.5[b]	Low	Lower plenum	15.45
L1-4	200% break[d]	Cold leg	17.5[b]	Low	Cold leg	15.45
L1-5[f]	200% break[d]	Cold leg	17.5[b]	Low	Cold leg	15.45

a. Simulates a 100% (50% of the break area in each leg) double-ended break in the hot leg of a four-loop PWR.

b. Blowdown valves orifices to open in 17.5 ms if primary coolant system pressure was 15.45 MPa. No tolerance given on this limit.

c. Cold leg emergency core coolant injection to be applied after completion of blowdown to separately evaluate "hot wall" effect.

d. Simulates a 200% (100% of the break area in each leg) double-ended break in the cold leg of a four-loop PWR.

e. Set for primary coolant system pressure of 15.45 MP.

f. Nuclear core installed, but not generating heat.

LOFT facility. Sufficient preceding experiments of increasing severity have been included to provide a controlled, predictable escalation in cladding temperature response and to check out any potential instrumentation or fluid system malfunction prior to the full power LOCE. Table II shows the selected parameters for the Power Ascension Test Series.

On December 9, 1978, the first nuclear blowdown experiment, LOCE L2-2, was performed at LOFT. Despite the fact that the cladding temperature was less than had been predicted, the test was a complete success.

The two most important experiments in this series are LOCEs L2-3 and L2-5 because the initial conditions for these two provide the conditions for all other test series in the experimental program. LOCE L2-3 is designated the standard best-estimate experiment and LOCE L2-5, with its assumption of offsite power loss and delayed emergency core cooling (ECC), is designated the standard 10 CFR Part 50.46 experiment.

SMALL AND INTERMEDIATE BREAKS TEST SERIES (SERIES L3)

The Small and Intermediate Breaks Test Series will consist of three LOCEs designed to study the effects of smaller than DECL primary coolant system ruptures. These experiments will be run at the best-estimate conditions (39.4 kW/m).

LOCE L3-1 will be a small cold leg break (0.0093 m^2) designed to provide an adequate data base for the development and assessment of small break computer models. The experiment will assume a concurrent loss of offsite power and loss of one low pressure injection system (LPIS) and one high pressure injection system (HPIS) train. For this experiment the broken loop hot leg, containing the steam generator and pump simulators, will be flanged out of the system. This experiment is being planned with minimum facility modifications to allow it to be performed early in the LOFT experiment schedule.

TABLE II

SUMMARY OF PARAMETERS FOR THE POWER ASCENSION TEST SERIES

LOCE[a]	Power Level (kW/m)	Primary Coolant System Flow (kg/s)[b]	Temperature (K)[b]	Offsite Power	Fuel Condition	Comments
L2-2	26.3	186.4	23.9	On	Unpressurized	Completed
L2-3	39.4	181.6	35.8	On	Unpressurized	Completed
L2-4	52.5	241.9	35.8	On	Unpressurized	The center fuel module is to be removed and examined (both nondestructive and destructive examinations are to be conducted).
L2-5	39.4	181.6	35.8	Off	Unpressurized	
L2-6	39.4	181.6	35.8	On	Prepressurized center module (2.41 MPa)	The center fuel module is to be replaced with a module with pressurized fuel rods.

a. All tests are full-area (200%) DECL breaks and assume loss of one low-pressure injection system and one high-pressure injection system train.

b. A total core peaking factor of 2.43 is assumed.

The remaining two experiments in this series are as yet undefined. A variety of options are open to study, on the basis of the data obtained in LOCE L3-1. Options under discussion include varying the cold leg break size, adding operator intervention, and opening the pressurizer relief valve. Facility modifications are also being considered. The main modification would be the lowering of the pump loop on the intact loop to an elevation more characteristic of that of PWRs. An instrumented break plane spool piece is also being considered to allow more accurate measurement of the break flow.

ALTERNATE EMERGENCY CORE COOLING SYSTEMS TEST SERIES (SERIES L4)

The five LOCEs of the Alternate Emergency Core Cooling Systems Test Series are proposed to directly compare various methods of emergency core cooling used throughout the world. The experiments will be initiated by double-ended cold leg ruptures run at standard best-estimate conditions as used in LOCE L2-3 of the Power Ascension Test Series. Table III summarizes the tests of this series.

TABLE III

SUMMARY OF PARAMETERS FOR ALTERNATE EMERGENCY CORE COOLING SYSTEMS TEST SERIES

LOCE[a]	Linear Heat Generation Rate (kW/m)	ECC Injection Location
L4-1	39.4	Lower plenum
L4-2	39.4	Hot leg
L4-3	39.4	Hot leg and cold leg
L4-4	39.4	Downcomer
L4-5	39.4	Cold leg upper plenum with inlet annulus pressure equalization

a. All tests will simulate a 200% DECL LOCA and will assume the loss of one LPIS and one HPIS train.

LOCE L4-1 will utilize lower plenum injection.

LOCE L4-2 will utilize hot leg injection, with the injection point located in the intact loop.

LOCE L4-3 will simulate a combined hot leg/cold leg injection system. Coolant volume fractions to be injected into each intact leg will be scaled from an existing plant which utilizes the system, such as Biblis Block A & B, Federal Republic of Germany. The total ECC volume will remain identical to that of the other experiments.

LOCE L4-4 will utilize direct downcomer injection.

LOCE L4-5 will be run with cold leg injection and will utilize a mockup of the Babcock & Wilcox Company vessel vent valves. These valves are a series of eight valves installed in the core support shield to provide direct flow from the upper plenum to the downcomer in the event the upper plenum pressure exceeds that of the downcomer. This valve arrangement is postulated to allow increased fluid circulation during a LOCA, enhancing the ECC system during reflood. Hopefully, the reflood assist bypass valves connecting the LOFT broken loop legs can be used to simulate the vent valves. If not, a major plant modification will be required.

The LOFT facility, as now designed, has ECC injection ports located in the intact loop hot leg, intact loop cold leg, upper plenum, lower plenum, and vessel downcomer. A modification to the upper core support structures may be required if analysis indicates the structures are incapable of handling the thermal stress caused by injected subcooled emergency core coolant.

HOT LEG RUPTURE TEST SERIES (SERIES L5)

The Hot Leg Rupture Test Series consists of two LOCEs designed to study core and system response to a major hot leg pipe rupture. Each LOCE will simulate a 200% (100% of the break area in each leg) double-ended offset shear in the hot leg of a four-loop PWR. The two LOCEs

TABLE IV

SUMMARY OF PARAMETERS FOR HOT LEG RUPTURE TEST SERIES

Parameter	LOCE L5-1	LOCE L5-2
Power level (kW/m)	39.4	39.4
Primary coolant flow (kg/s)	181.6	181.6
Core ΔT (K)	35.8	35.8
Primary coolant pumps	On	Coastdown
Broken loop resistance	Low	High
ECC delay	No	Yes

(summarized in Table IV) are a standard best-estimate experiment and a standard 10 CFR Part 50.46 experiment, similar to LOCEs L2-3 and L2-5.

If minimal differences are observed between LOCEs L2-3 and L2-5 of the Power Ascension Test Series, the need to run LOCE L5-2 for comparison will be eliminated. In this event, a doubled-ended offset shear pump suction leg break may be substituted.

NON-LOCE TRANSIENT TEST SERIES (SERIES L6)

The Non-LOCE Transient Test Series consists of an undetermined number of non-LOCE transients designed to study the integrated system response to anticipated transients without scram (ATWS) and to operational transients. The overall purpose of this test series is to provide tests that can be performed between major LOCEs, thus increasing the data that can be obtained from the LOFT facility.

Specific transients to be used in the L6 test series have not been selected. Table V lists some of the tests that preliminary studies show might be feasible. These tests are to be run at 39.4 kW/m unless safety analyses show that the power must be reduced.

TABLE V

POTENTIAL NON-LOCE TEST SERIES TRANSIENTS

1. Uncontrolled rod cluster control assembly bank withdrawal from a subcritical condition
2. Uncontrolled rod cluster control assembly bank withdrawal at power
3. Uncontrolled boron dilution
4. Partial loss of forced reactor coolant flow[a]
5. Loss of external electrical load or turbine trip[a]
6. Loss of normal feedwater[a]
7. Loss of offsite power to station auxiliaries[a]
8. Excessive heat removal due to feedwater system malfunction
9. Excessive load increase[a]
10. Accidental depressurization of the primary coolant system[a]
11. Complete loss of forced reactor coolant flow
12. Single rod cluster control assembly withdrawal at full power[a]

a. Potential ATWS event.

STEAM GENERATOR TUBE RUPTURE TEST SERIES (SERIES L7)

The Steam Generator Tube Rupture Test Series will consist of two LOCEs designed to investigate the behavior of a PWR in the event of a steam generator tube rupture (SGTR) concurrent with a LOCA. Both LOCEs will simulate a DECL rupture at 39.4 kW/m and an identical steam generator tube rupture, a 16-tube rupture, at the start of core reflood. One will be a standard best-estimate experiment and the other will be a standard 10 CFR Part 50.46 experiment. Table VI summarizes these two LOCEs.

Saturated water will be injected into the intact loop hot leg to simulate the steam generator tube rupture. The flow rate will be

TABLE VI

SUMMARY OF PARAMETERS FOR STEAM GENERATOR TUBE RUPTURE TEST SERIES

Parameter	LOCE L7-1	LOCE L7-2
Power level (kW/m)	39.4	39.4
Primary coolant flow (kg/s)	181.6	181.6
Core ΔT (K)	35.8	35.8
Primary coolant pumps	On	Coastdown
Broken loop resistance	Low	High
ECC delay	No	Yes
Number of tubes ruptured	16	16
Injection rate (kg/s)	4.82[a]	4.82[a]
Time injection starts after blowdown	Start of reflood	Start of reflood
Water temperature (K)	547	547

a. Volume scaled.

scaled to LOFT using volume scaling. Water for the simulation will be nonborated, demineralized water. Plant modifications will be required prior to running either of the Series L7 LOCEs.

TEST SCHEDULE

The present LOFT test schedule is presented in Table VII. The philosophy behind this schedule is to complete the Power Ascension Test Series, and then perform a single experiment from each of the remaining test series. This approach will allow the fullest possible range of data to be included in the planning decisions for the remaining experiments. This philosophy and the schedule could change due to U.S. Nuclear Regulatory Commission direction if special licensing requirements are identified.

TABLE VII

LOFT LOSS-OF-COOLANT EXPERIMENT SEQUENCE

LOCE	Date[a]	Fuel Changes	Comment
L2-2	December 1978		Complete
L2-3	May 1979	CFM[b]	Complete
L3-1	April 1981		If communicative break is required, major modifications will be necessary
L2-5	October 1979	CFM	
L2-4	April 1980	Core	
L2-6[c]	October 1980	Core[d]	
L4-1	October 1981		
L5-1	March 1982	CFM	
L7-1	September 1982		Major modifications required
L3-3	February 1983	Core	
L4-5	September 1983		If reflood assist bypass valves cannot be used, test will require major modifications
L4-3	March 1984	CFM	Upper core support structure analysis required
L4-2	September 1984		
L7-2	February 1985	Core	
L4-4	October 1985		
L3-2	March 1986		
L5-2	August 1986		

a. Approximate.

b. CFM = center fuel module to be replaced following test.

c. The first ATWS test (Test L6-1) is tentatively schedule following LOCE L2-6 (October 1981).

d. Prepressurized center fuel module for Test L2-6 only.