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ECC DELIVERY AND DISTRIBUTION IN SCALED PWR EXPERIMENTS

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SUMMARY

Reactor Safety research currently being conducted in the LOFT(1) and Semiscale(2) experimental facilities has produced experimental results relevant to emergency core coolant (ECC) licensing calculations. LOFT, Semiscale, and commercial PWRs are related through a volume scaling rationale(3) which permits identification of the trends in the thermal-hydraulic phenomena in scaled research facilities. Additionally, the thermal-hydraulic phenomena in PWRs can be bounded through application of the scaling rationale. The experimental ECCS results relevant to licensing were obtained principally from the two LOFT experiments described in Table I. Experimental results from the Semiscale program and other LOFT experiments are used where required in extending the trends of the thermal-hydraulic phenomena in the scaled systems to commercial PWRs. ECCS capability is discussed herein in terms of the ECC delivery delay to the lower plenum and the undelivered ECC to the reactor vessel during ECCS operation.

The basic (volume) scaling rationale leads to distortion of the surface area-to-volume ratio which, as scaled systems are made smaller, increases the relative heat transfer from the walls to the fluid. This can cause delay in delivery of ECC to the lower plenum (assuming cold leg ECC injection) through the mechanisms of steam generation and counter current flow. The scaling rationale for the LOFT and Semiscale

TABLE I

LOFT LOCE System Configuration and Initial Conditions

Parameter	L1-4	L1-5
Configuration		
Pipe break:		
Location	Cold leg	Cold leg
Size (%)	200	200
Opening time (ms)	18	19.5
Core	Simulator for ΔP	Nuclear core
Primary system pump operation	Power terminated at T_0 +< 1 s	Powered to T_0 + 70 s
Broken loop pump simulator[a]	Locked rotor (K = 20.70)	Operating pump (K = 9.95)
Intact loop resistance	Low resistance (K = 131.7)	Low reistance (K = 131.7)
ECC systems	HPIS, LPIS, and accumulator	HPIS, LPIS, and accumulator
ECC injection location	Intact loop cold leg	Intact loop cold leg
ECC systems actuation mode:		
Accumulator	Pressure	Pressure
LPIS	Time	Pressure-level
HPIS	Time	Pressure-level
Secondary coolant system	Primary coolant system saturation conditions, no flow	Primary coolant system saturation conditions, no flow
Initial conditions		
Primary system:		
Pressure (MPa)	15.65	15.45
Temperature (K)	552.15	555
Mass flow (kg/s)	268.4	176.1
Boration (ppm)	1494	3087
ECCS accumulator:		
Pressure (MPa)	4.14	4.17
Temperature (K)	306.15	304
Boration (ppm)	3307	3155
Injected volume (m^3)	2.05	[illegible] 73
Gas volume (m^3)	1.16	0.97

[a] Darcy K factor based on 0.016 m^2 flow area.

systems kept the active core length (1/2 PWR 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). Counter current flow, therefore, is expected to have a larger effect on ECC delay in Semiscale than in LOFT.

The hot wall induced delay in ECC delivery follows the expected dependency on the surface area-to-volume ratio in LOFT and Semiscale experiments. Semiscale hot wall delay is approximately 10 s, whereas in LOFT the hot wall delay is in the range of 0.5 to 1.0 s. The hot wall delay range in LOFT applies for conditions at ECC injection time ranging from 0.34 MPa, 555 K wall temperature to 4.14 MPa, 520 K wall temperature. The former set of conditions were for a quiescent system long after saturated blowdown with the reactor vessel empty of fluid. The latter set of conditions were for a normally actuated ECCS during saturated blowdown wherein the pressure is rapidly decreasing with significant mass flow in the downcomer. The wide range of conditions show that, in the LOFT downcomer, ECC delay to the lower plenum is not affected significantly by either hot walls or existing counter current flow. The ECC hot wall delay effect in a PWR (with a downcomer L/D = 1.3) is considered to be equal to or less than that in LOFT. Thus, the ECC hot wall delay does not represent a significant deterrent to the intended operation of ECCS designs.

The undelivered ECC is defined to include the fluid expelled or bypassed out the break and the fluid stored in the system piping. The undelivered ECC in LOCE L1-4 was essentially the same as that in LOCE L1-5. Approximately 30% of the ECC was bypassed out the break in LOFT[4] by the time the accumulator emptied. An additional 15% of the ECC was stored in the piping at that time. After the accumulator emptied the refill rate was essentially equal to the pumped ECC injection rate. After steady state conditions were reached the flow out the break equaled the pumped ECC injection rate.

The ECC bypassed in Semiscale is larger than in LOFT and is attributed to the difference in downcomer fluid behavior. The implication is that, since the LPWR downcomer fluid behavior is considered to be similar to that in LOFT and since the Semiscale ECC bypass fraction is larger than that in LOFT, the ECC bypass fraction in LPWRs at the time the accumulator empties will be less than (or no greater than) that in LOFT ($\leq$ 30%). These results were not found to depend on the operation of the primary coolant pumps (PCPs). With reference to Table I, the PCPs were powered in LOCE L1-5, were as in LOCE L1-4 the pumps were tripped at the initiation of blowdown.

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1. D. L. Reeder, "LOFT System and Test Description (5.5 Foot Nuclear Core 1 Loss-of-Coolant Experiments)," TREE-NUREG-1208 (July 1978).

2. L. J. Ball, et al., "Semiscale Program Description," TREE-NUREG-1210 (May 1978).

3. L. J. Ybarrondo, S. Fabic, P. Griffith, and G. D. McPherson, "Examination of LOFT Scaling," presented at the ASME Winter Annual Meeting, New York , New York (November 17-22, 1974).

4. L. P. Leach and L. J. Ybarrondo, "LOFT Emergency Core Cooling System Experiments: Results from the L1-4 Experiment," Nuclear Safety, Volume 19, No. 1, January-February 1978.