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ECCS ACCUMULATOR PERFORMANCE IN SCALED PWR EXPERIMENTS

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SUMMARY

Best-estimate models for pressurized water reactor (PWR) loss-of-coolant (LOCA) analysis require a realistic assessment of the thermodynamic behavior of the N_2 gas in the accumulators of an emergency core cooling system (ECCS). The LOFT[(1)] and Semiscale[(2)] reactor safety research facilities, which are scaled to a commercial PWR[(3)], have provided experimental information which identifies the thermodynamic behavior of scaled ECCS accumulators. The thermodynamic behavior of PWR accumulators can be identified from the experimental results through the scaling rationale.

ECCS accumulators are large tanks partially filled and pressurized with N_2. The accumulators are isolated from the primary system piping by two check valves. Reduction in system pressure due to a pipe break causes the check valves to open and accumulator flow to begin. The thermodynamic behavior of the N_2 gas in the accumulator can be characterized quite simply by a polytropic gas constant. RELAP4 calculations on the LOFT system show typical differences of about 15% in accumulator flow rates between polytropic gas constants of 1.0 (isothermal) and 1.4 (isentropic) where the isentropic case corresponds to the lower flow rate.

The LOFT and Semiscale systems contain sufficient instrumentation to allow measurement of accumulator pressure and calculation of accumulator

N_2 volume. The polytropic gas constant, n, is calculated as a function of time from accumulator N_2 pressure and volume data with the equation

$$P_o V_o^{\,n} = P(t)\ V(t)^n$$

where

P_o, V_o = initial pressure and volume, and
$P(t)$, $V(t)$ = time dependent pressure and volume.

Calculations of the gas constant for the accumulator N_2 expansion in LOFT experiment L1-4[4] and the Semiscale baseline ECC experiment S-04-6[5] are shown in Figure 1 and indicate well defined values of the gas constant that are different for the two accumulator sizes. The gas constant is dependent primarily on two parameters, the N_2 gas expansion rate and surface-to-volume ratio. The loss-of-coolant transients in LOFT and Semiscale are typical of the transients that are postulated to occur in the hypothetical full double ended offset shear of a primary coolant pipe in commercial plants. Thus, the N_2 gas expansion rates in the LOFT and Semiscale accumulators are similar and in turn are designed to be similar to gas expansion rates in PWRs for typical LOCA transients. The expansion rates are sufficiently slow to permit heat transfer to occur. Thus, the second parameter, the N_2 gas surface area-to-volume ratio, becomes the principle parameter affecting the thermodynamic behavior of ECCS accumulator systems.

The values of the surface area-to-volume ratio and corresponding N_2 gas constant for LOFT and Semiscale are listed in Table I along with the value of the ratio for a PWR accumulator and the expected value of the PWR accumulator N_2 gas constant. As the surface area-to-volume ratio decreases the polytropic gas constant increases and indicates that the gas expansion in a PWR accumulator approaches an isentropic expansion. The LOFT and Semiscale experimental results indicate that, for licensing calculations, an isentropic expansion of the N_2 gas in the accumulator is preferable to ensure a valid technical basis for assessment of the conservatism in ECCS accumulator design.

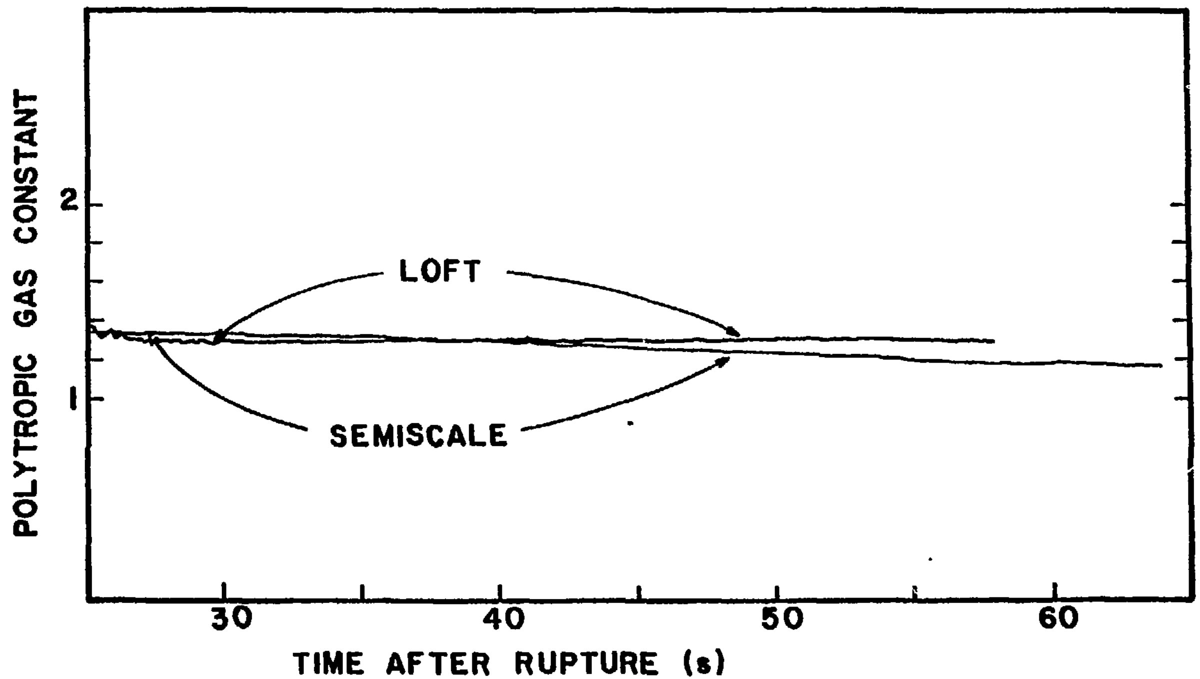

Figure 1. LOFT and Semiscale Accumulator Polytropic Gas Constants.

TABLE I

ACCUMULATOR SYSTEMS COMPARISON

System	Surface Area/Volume (m^{-1})	Polytropic Gas Constant
Semiscale	16.6	1.18
LOFT	5.8	1.3
PWR	2.4	$1.3 < n < 1.4$ (expected)

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