LOFT SMALL BREAK EXPERIMENTS:
Importance and Effectiveness of Steam Generators and Natural Circulation

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Both four and one inch break diameters in a commercial pressurized water reactor (PWR) have been simulated in LOFT small break experiments. LOFT Experiments (LOCAs) L3-1 and L3-7, respectively, are examples. During L3-1 the fluid leaving the break removed sufficient energy to depressurize the system while the core remained covered with fluid. The U-tube steam generator was not needed to recover the system. In L3-7, a simulated one inch diameter break, the steam generator was required and was effective in both removing energy to depressurize the system and providing the operator a means of controlling the primary system depressurization rate.

About six minutes after L3-1 initiation, the primary system pressure dropped below the secondary system pressure and the steam generator transitioned from a system heat sink to a potential heat source. From that time on the energy loss from the break alone was sufficient to depressurize the system. Had the steam generator not been a heat sink the first six minutes, calculations indicate the system would have depressurized, although a bit more slowly. These results confirm calculations for commercial PWRs that the steam generator is not needed to recover the system from single failure breaks, whose effective diameter is 4 inches or greater.

The more likely accident is a break in a line smaller than 4 inches in diameter. The Combustion Engineering System 80 PWR has 225 lines penetrating the primary coolant boundary. Eighty-five per cent (85%) of the penetration lines are less than four inches in diameter. This was one of the reasons for selecting the one inch break diameter simulated in LOCE L3-7. Sixty-four per cent (64%) of the penetration lines in the System 80 are one inch in diameter or less.

During L3-7, the steam generator was needed to aid system depressurization and furnished a means for the operator to expedite recovery indirectly, without opening an additional break in the primary system. The system continued to depressurize throughout the transient even though high pressure injection was terminated for a time. When the operator initiated steam generator secondary feed-and-bleed, the primary system depressurization rate substantially increased, hastening system recovery.

The break was isolated about 2 hours after experiment initiation. The steam generator was then the only means, besides heat losses to the environment, of removing energy from the system. The system coolant, which was being replenished by high pressure injection, subcooled. The primary system pressure rose and the steam generator, augmented by operator initiated feed-and-bleed, continued to cool the reactor core.

Natural circulation, the flow mechanism necessary for effective steam generator operation, started after the primary coolant pumps coasted down, one minute
after experiment initiation. Both single-phase and two-phase natural circulation flow modes, from that time on, provided the flow from the core to the steam generator and return. Neither void generation in the core coolant nor the injection of cold emergency-core-coolant (ECC) into the flow path measurably influenced natural circulation.

The results from LOFT Experiments L3-1 and L3-7 show that the steam generator is needed as a system heat sink during the smaller break sized, but more probable, loss-of-coolant accidents. When needed, the steam generator is effective in removing the heat required to keep the system in a cool, stable transition process while proceeding toward recovery. This process can be expedited by operator initiated steam generator secondary feed-and-bleed without opening another break in the primary system. These results will be used in accessing the computer codes used to calculate commercial PWR transient response and for devising and verifying emergency operating procedures.
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GENERATORS AND NATURAL CIRCULATION

J. H. LINEBARGER
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CONTENTS

SYSTEM

4" BREAK (LOCE L3-1)

1" BREAK (LOCE L3-7)

• STEAM GENERATOR

• NATURAL CIRCULATION

CONCLUSIONS
L3-1 SYSTEM PRESSURE

PRESSURE (psia)

TIME (sec)

UNCERTAINTY ± 32.0 psia

HPIS

R.V. SATURATED

BREAK UNCOVERED

ACCUMULATOR

BREAK COVERED

NITROGEN

STEAM BLEED

LPIS
L3-1 PRIMARY AND SECONDARY SYSTEM PRESSURE COMPARISON

UNCERTAINTY ± 32.0 psia

BREAK UNCOVERED
\( P_{PRI} < P_{SEC} \)

ACCUMULATOR ON

BREAK COVERED

NITROGEN ENTERS SYSTEM

S.G. SECONDARY FEED & BLEED

END OF NC

PRESSURE (psia)

TIME (sec)
L3-7 PRIMARY AND SECONDARY SYSTEM PRESSURE COMPARISON

UNCERTAINTY ± 16.0 psia

- - PRIMARY

- - SECONDARY

UPPER PLENUM SATURATED

S.G. SECONDARY FEED & BLEED

R.V. FLUID THERMAL NON-EQUILIBRIUM

BREAK ISOLATED

TIME (sec)

JHL-2E
L3–7 INTACT LOOP HOT LEG AND REACTOR VESSEL FLUID VELOCITIES

UNCERTAINTY ±0.5 ft/sec
L3-7 Reactor Vessel Fluid Temperatures and Velocity

Uncertainties:
- Temp. ±5.4 °F
- Vel. ±0.5 ft/sec

- LP Temp
- UP Temp
- SAT. Temp
- UP Velocity

- Upper Plenum Saturation
- Lower Plenum Saturation
- Pump Off

Time (sec)

Temperature (°F)

Velocity (ft/sec)
L3-7 REACTOR VESSEL FLUID TEMPERATURES

UNCERTAINTY ±5.4°F

TEMPERATURE (°F)

TIME (sec)

LP SATURATED

UP SATURATED

UP SUBCOOLED

LP SUBCOOLED
CONCLUSIONS

4" BREAKS AND LARGER - STEAM GENERATOR NOT NEEDED

1" BREAKS AND SMALLER -

- STEAM GENERATOR NECESSARY AND EFFECTIVE SYSTEM
  HEAT SINK

- NATURAL CIRCULATION IS STABLE, REVERSIBLE FLOW
  MODE

- SECONDARY FEED-AND-BLEED EXPEDITES RECOVERY