UNITED STATES
NUCLEAR REGULATORY COMMISSION
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MEMORANDUM FOR: Thomas E. Murley, Director
Office of Nuclear Reactor Regulation

FROM: Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 154, "WATER-STEAM COUNTERCURRENT FLOW LIMIT IN A FULL SCALE HOT LEG"

This Research Information Letter transmits the results of water-steam countercurrent flow limit (CCFL) tests in a hot leg of the upper plenum test facility (UPTF). The UPTF is a full-scale model of a four-loop 1300 MWe pressurized water reactor with simulated core, steam generators, and locked rotor pumps. The facility is designed to simulate the end of blowdown, refill and reflood phases of a large-break loss-of-coolant accident (LBLOCA), as well as some conditions associated with small break LOCA's. The Emergency Core Cooling systems for LBLOCA testa are fully simulated. The reactor core is simulated with injection of steam and water. The downcomer, lower plenum and upper plenum are prototypic PWR hardware. Full-size pipes are used for three intact loops and one broken loop.

1. Regulatory Issue

When a substantial amount (order of 50%) of reactor coolant is lost from the primary coolant system during a small-break loss-of-coolant accident (SBLOCA), natural circulation of coolant around the primary system can not be maintained. The coolant flow pattern then changes to a reflux condenser mode where the steam generated in the core flows to the steam generator while the condensate formed in the U-tube steam generator flows back to the reactor vessel in the opposite direction to the steam flow. Under such circumstances, a safety concern arises because steam may limit or prevent the water downflow and thus the ability to extract the decay heat from the core may be limited or lost.

NRR endorsed investigating this countercurrent flow phenomenon in its letter dated May 10, 1984 (Attachment A). In addition, NRR requested in its letter dated September 12, 1984, that the RES-developed computer codes be sufficiently verified so that they can be used to calculate Chapter 15 events and other operating events (Attachment B, last paragraph on P. 5). Therefore, the objectives of this study were:

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A. To determine whether the flow of condensate back to the vessel is limited or prevented by the steam in the full scale UPTF hot leg, and

B. To verify the TRAC computer code for application to the above countercurrent flow phenomenon.

2. Conclusion

A series of experiments in the UPTF at two different pressures (3 and 15 bars) show that a CCFL curve lies far above the region of typical PWR reflux condensation conditions (See Figure V.C-1 of Attachment C, "Summary of Results from the UPTF Hot Leg Separate Effects Test, Comparison to Scaled Test and Application to U.S. PWR's"). It is estimated that the steam flow would have to be increased about 2.5 times before a CCFL condition is encountered. Therefore, a large margin exists between expected PWR conditions and the CCFL point, indicating that stable steam-water countercurrent flow can be maintained in hot legs during a small-break LOCA. This conclusion confirms the results from earlier small-scale test results as indicated in Figure V.C-1 of Attachment C.

The predictive capability of the TRAC computer code was examined by the Los Alamos National Laboratory (LANL) for this hot leg countercurrent flow condition. The results are documented in a report entitled "Post-Test Analysis of the UPTF SBLOCA Test with TRAC-PF1/MOD1 and MOD2" (Attachment D). The results show that TRAC-PF1/MOD1 underpredicts the steam flow rates for the high liquid downflow region. From a safety standpoint, the underprediction of steam flow is conservative and thus acceptable. Therefore, TRAC-PF1/MOD1 can be used to determine at which steam flow rate the liquid downflo is completely held back.

3. Regulatory Implications

Since the safety concern of adequate core cooling during the reflux condensation period of a SBLOCA is removed for PWR's with U-tube steam generators, no specific regualtory action is recommeded. With respect to TRAC code applicability to a PWR, the code can be used to determine whether the liquid downflow toward the vessel can be held up in a hot leg by the opposing steam flow.

4. Restriction on Application

The UPTF hot leg CCFL test results were obtained at pressures much lower than that expected during a SBLOCA; 3 and 15 bars vs. 80 bars. However, the low pressure data can be scaled to a higher pressure through use of appropriate dimensionless variables. In addition, small-scale

(Semiscale) test results obtained at higher pressures (62 bars) were found to be consistent with the lower pressure data obtained from the UPTF, evidencing that the extrapolation with respect to pressure is reasonable.

5. Unresolved Questions

With respect to steam-water CCFL's in PWR hot legs during a SBLOCA, there are no unresolved questions. The safety concern has been removed.

Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

Attachments: As stated