UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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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. 165,
RESOLUTION OF ISSUE: THE EFFECTIVENESS OF UPPER PLENUM INJECTION FOR EMERGENCY CORE COOLING

Upper plenum injection (UPI) is used to cool the core in the event of a loss-of-coolant accident (LOCA) in Westinghouse two-loop plants. This Research Information Letter transmits the results of tests and associated analyses on emergency core coolant (ECC) injection into the upper plenum. This work was conducted as part of the 2D/3D International LOCA Research Program.

In its 1/11 volume-scale Cylindrical Core Test Facility (CCTF), the Japan Atomic Energy Research Institute (JAERI) conducted five UPI tests, which were evaluated and reported on by MPR Associates, Inc. (Enclosures A1 and A2). Los Alamos National Laboratory (LANL) analyzed these same tests with the TRAC computer code (Enclosure B). The German Federal Ministry of Research and Technology (BMFT) conducted an additional full-scale UPI test (actually larger than full-scale by a factor of 2) in its Upper Plenum Test Facility (UPTF). MPR Associates also evaluated this test (Enclosure C), and LANL performed accompanying TRAC analysis (Enclosure D).

1. Regulatory Issue

Six plants of Westinghouse design are equipped with emergency core cooling systems that inject water into the upper plenum as opposed to the cold-leg. For such configurations, the possibility was suggested that upflowing steam might prevent the injected water from flowing downwards into the core, thus preventing effective core cooling. This phenomenon is known as a countercurrent flow limitation (CCFL), or flooding. In this event, water would pool above the core in the upper plenum. Furthermore, the upflowing steam might entrain the pooled water from the upper plenum and carry it through the hot-legs to the steam generators, where it would evaporate to create back pressure, known as steam binding. The subject of UPI performance was, therefore, deemed a significant issue and NRR requested that applicable data be obtained as part of the 2D/3D program (Enclosure E).

2. Conclusions

The 2D/3D data and associated analyses showed that UPI is effective in cooling the core over a range of decay heat levels that bounds PWR conditions (less than 1.21 KW/M). Steam binding was concluded not to be significant, as most of the steam was condensed by the UPI water in the upper plenum.

CCFL did not occur at the interface between the core and the upper plenum. Rather, the CCTF and UPTF data showed that water flowed from the upper plenum downwards into the core in certain preferential locations. The core flow divided itself into two regions and a type of circulation cell was established, with one region being predominantly liquid downflow and the other region primarily two-phase steam/water upflow. The downflow region did not always form at the same initial location within the core-upper plenum interface, rather, there was a degree of randomness in its location, indicating that the facility did not have a designed-in bias. Once the downflow location was established, however, it stayed put.

As the liquid descended further through the core, it tended to spread as it encountered upflowing steam. Additional steam was generated by interaction of the falling, spreading water with the hot core, and some downflowing water was entrained in the upflowing two-phase fluid. The downflow area decreased with the size of facility scale and increased with the Froude number of the ECC jet. For PWR conditions the downflow area is estimated to be about 30-40%. In the two-phase upflow region, the core cooling was comparable to cold-leg injection tests. In the downflow region, the core cooling was somewhat better (typically about 30° K lower cladding temperatures) than the two-phase upflow region, especially in the upper half of the core.

Throughout the tests the net flow out of the bottom of the core was downwards. This was a positive result, since the effect was to refill and reflood the reactor vessel rather than to entrain water to the steam generator. There was more than enough water in the downflow region to supply the upflow region. This was true even for conditions simulating the loss of one ECC train. The excess downflowing liquid simply flowed out the break via the lower plenum and downcomer.

The TRAC computer code (TRAC-PF1/MOD1) predicted major trends in the data reasonably well, although certain phenomena such as the downflow rate (overpredicted) and the core void distribution were in lesser agreement (underpredicted at the top of the core). The location of major downflow varied from test to test and this variation was not always predicted by TRAC. TRAC predicted peak clad temperatures (PCT's) within 80° K for a single pump failure case and within 20° K for a best-estimate case. In all cases, TRAC correctly predicted that the net flow at the core inlet was downward.

Based on the TRAC predictions of UPI data in the two different-scale facilities (CCTF and UPTF), as well as a more extensive comparison with other test data, it is possible to state that TRAC can be used to predict the main characteristics of UPI behavior in a PWR.

3. <u>Regulatory Implications</u>

The 2D/3D program met the NRR need for UPI data. The resultant data are an important reference in the evaluation of UPI models used for LOCA analysis. These data strongly supported NRR's approval of the Westinghouse UPI submittal, which utilized the Westinghouse version of NRC's COBRA/TRAC code (WCOBRA/TRAC), and which was demonstrated to meet the guidance specified in SECY 83-472.

4. <u>Restriction on Application</u>

Both the CCTF and UPTF facilities differ from an actual Westinghouse two-loop UPI plant due to scaling compromises. For instance, the CCTF is not only smaller, but also it has four loops instead of two. In addition, the injection ports are located inside the upper plenum via special pipes coming down from the upper head whereas in a Westinghouse plant the injection ports are terminated at the downcomer inner wall. UPTF does not have a heated core, is about twice as large as a Westinghouse UPI plant, and has an injection to two of the four hot-legs rather than to geometrically representative UPI nozzles. For these and other differences, the CCTF and UPTF results should not be used directly to infer PWR behavior. Instead, appropriate supporting code analyses should be employed to determine the performance of a PWR.

5. <u>Unresolved Questions</u>

There are no unresolved questions with respect to understanding UPI performance. The CCTF and UPTF data along with the TRAC code are sufficient to evaluate licensee UPI models.

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Enclosures:
See next page.

Enclosures:
A1. CCTF-II Research Information Report
for Tests Related to Upper Plenum
Injection (UPI), MPR 933, Vol 1.
A2. CCTF-II Research Information Report
for Tests Related to Upper Plenum
Injection (UPI), MPR 933, Vol 2.
B. 2D/3D Program Technical Note:
CCTF Core-II Upper Plenum
Injection TRAC-PF1/MOD1 Analysis
Summary, LA-2D/3D-TN-86-16
C. Summary of Results from the UPTF
Upper Plenum Injection (UPI)
Separate Effects Test, Comparison
to Previous Selected Tests, and
Application to U.S. Pressurized
Water Reactors.
D. TRAC-PF1/MOD2 Analysis of UPTF Test
20 Upper Plenum Injection in a
Two-Loop PWR, LA-CP-90-2.
E. Memorandum from R. Mattson to O. Bassett,
April 1, 1982: "Experimental Data Needs
from the 2D/3D Program for Plants with UPI."