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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 (RIL) NO. 163
TEST RESULTS FROM THE 2D/3D CYLINDRICAL CORE TEST FACILITY (CCTF)

This Research Information Letter (RIL) transmits the results of tests conducted in the Cylindrical Core Test Facility (CCTF) by the Japan Atomic Energy Research Institute (JAERI) under the 2D/3D International Loss-of-Coolant Accident (LOCA) Research Program. The other parts of this program include the Slab Core Test Facility (SCTF) (Reference: RIL 157) and the Upper Plenum Test Facility (UPTF). Conduct of CCTF constituted a major experimental and analytical effort.

The CCTF was a low pressure (up to 6 bar) facility for investigating the refill and reflood phases of LOCA. The CCTF was a 1/21-scale model of a four-loop 1100 MWe pressurized water reactor (PWR). It had a full-height pressure vessel, core, and downcomer, as well as upper and lower plena. The core contained 2048 rods, 1824 of which were electrically heated. In addition, it had four full-length primary loops, each containing passive pump simulators and active steam generators.

Two test series consisting of 49 tests were conducted. The data were analyzed by MPR Associates, Inc. and documented in the enclosed two reports:

1. "Research Information Report on the Results of the Core-I Test Series at the Japan Atomic Energy Research Institute Cylindrical Core Test Facility," MPR-863, Rev. 1, Vol. 1 and 2, October 1985 (Enclosure 3).

2. "Research Information Report for the Cylindrical Core Test Facility (CCTF) Core-II Test Series (Excluding Tests Involving Upper Plenum Injection)," MPR-934, Vol. 1 and 2, April 1988 (Enclosure 4).

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Nine of the CCTF Core-I tests and eleven of the Core-II tests were analyzed by the Los Alamos National Laboratory (LANL) with the Transient Reactor Analysis Code (TRAC) and documented in the enclosed two reports:

1. "Research Information Report Results from TRAC Analysis of Cylindrical Core Test Facility Core-I Test Series," LA-2D/3D-TN-86-10, LANL, July 1986 (Enclosure 5).

2. "Summary Report of TRAC-PF1 Assessment against the CCTF Core-II Data," LA-CP-89-17, LANL, June 1989 (Enclosure 6).

1. Regulatory Issues

The results of CCTF tests and TRAC analyses contributed to the resolution of two regulatory issues:

A. The safety margin imbedded in 10 CFR 50.46 and Appendix K evaluation models.

B. The ability of TRAC to predict reflood.

The determination of safety margin in the models prescribed in 10 CFR 50.46 and Appendix K was the subject of many small-scale experiments in the 1970's and the early 1980's. The experimental results showed a large margin of conservatism in the Appendix K models; however, there was uncertainty in extrapolating these small-scale test results to full-size power reactors. The 2D/3D Program provided large scale data to satisfy the scaling concerns.

NRR endorsed investigating the safety margin in the Appendix K models in its memorandum of July 25, 1978 (Enclosure 1). NRR in its memorandum of September 12, 1984, endorsed (Enclosure 2) the need for having verified computer codes.

2. Conclusion

The CCTF tests support the conclusion that the Emergency Core Cooling System (ECCS) is adequate to reflood the core following a large break LOCA, and to limit peak clad temperatures to much less than allowed by 10 CFR 50 (1204 C, 2200 F). The PCT safety margin for the CCTF Core-I base case test, which is considered to underestimate the margin actually available in a PWR, is about 400C (720F). This is consistent with the results of the NRC code uncertainty study (NUREG/CR-5249) which shows that the margin expected in a Westinghouse 4-loop PWR with 95% probability is 590F.

The CCTF test showed that the available PCT margin varied depending on several parameters, including downcomer wall temperature, ECC flow rates, loop resistances, initial clad temperatures, cold-leg loop seals, and containment and vessel pressures. Therefore, the PCT margin in a given PWR will depend on the actual values of these parameters.

TRAC-PF1/MOD1 predicted the behavior of refill and reflood processes reasonably well except:

1. Liquid distribution in the core and its entrainment to the upper plenum. The TRAC prediction of the entrainment and de-entrainment of liquid in the subsequent components (upper plenum, hot legs, and steam generators) cannot be evaluated from the present analyses because TRAC does not allow enough liquid to be entrained to the upper plenum, which is the first component after the core. This modeling is being improved in the final version of the code (TRAC-PF1/MOD2) to be released by the end of 1989.

2. Condensation of steam by cold ECC. Difficulties with the condensation model are indicated by discrepancies in liquid temperatures entering the downcomer and excessive oscillations in cold legs and the downcomer. This is also being resolved in TRAC-PF1/MOD2.

Overall, our conclusion, based on these results as well as those of SCTF and our code scalability, applicability and uncertainty (CSAU) study, is that TRAC-PF1/MOD1 is suitable for use in analyzing large-brake LOCA in PWR's.

3. Regulatory Implications

The CCTF test results served as a major source of data for revising the ECCS rule, which took effect in October 1988. Further regulatory actions are not needed.

4. Restriction on Application

The CCTF, although large, is still a scaled facility, and thus the results are subject to interpretation through a code such as TRAC before they are applied to PWRs. More recent tests conducted in UPTF show that the CCTF test results tend to be conservative. The UPTF results will be the subject of a future RIL when the analysis is completed.

5. Unresolved Questions

Major factors affecting the PCT include ECC downcomer bypass and liquid de-entrainment in the upper plenum, hot legs, and steam generator inlet plena. The resultant uncertainties from these factors were evaluated and reported in NUREG/CR-5249. Forthcoming UPTF results are expected to reduce these uncertainties.

Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

Enclosures:
1. NRR Position on LOCA/ECCS Research Commission Papers
2. NRR Thermal/Hydraulic Research Needs
3. Research Information Report on the Results of the Core-I Test Series at the JAERI Cylindrical Core Test Facility, Vol. 1 and 2
4. Research Information Report for the Cylindrical Core Test Facility (CCTF) Core-II Test Series (Excluding Tests Involving Upper Plenum Injection), Vol. 1 and 2
5. Research Information Report Results from TRAC Analysis of Cylindrical Core Test Facility Core-I Test Series
6. Summary Report of TRAC-PF1 Assessment Against the CCTF Core-II Data