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. 162, "REPORT ON THE RESULTS OF THE CORE-II TEST SERIES AT THE JAPAN ATOMIC ENERGY RESEARCH INSTITUTE SLAB CORE TEST FACILITY"

This Research Information Letter (RIL) transmits the results obtained from the Core II test series carried out at the Japan Atomic Energy Research Institute (JAERI) Slab Core Test Facility (SCTF). The SCTF was intended to study the reflood stage of a Large-Break Loss-of-Coolant Accident (LBLOCA) in a Pressurized Water Reactor (PWR). This work is part of the 2D/3D International Loss-of-Coolant Accident (LOCA) Research Program. A total of 25 tests were conducted, analyzed, and documented in "Research Information Report on the Slab Core Test Facility (SCTF) Core-II Test Series" (Enclosure C) prepared by MPR Associates, Inc. Ten of the tests were analyzed with the TRAC computer code by the Los Alamos National Laboratory and the results documented in "SCTF Core-II TRAC-PF1/MOD1 Analysis Summary" (Enclosure D).

The SCTF is a two-dimensional core thermal-hydraulic test facility with a full-height, full-radius (8 bundles), and one-bundle-width vessel containing approximately 2000 electrically heated rods. It is volume scaled 1:21. The primary loop is simulated with a hot leg, steam-water separator, pump simulator, intact cold leg, and a broken cold leg. The slab-shaped test vessel contains a downcomer and the upper and lower plena.

The results of SCTF Core-I test series were reported in 1988, RIL No. 157, "Report on the Results of the Core-I test series at the Japan Atomic Energy Research Institute Slab Core Test Facility." The main objective of SCTF Core-I test series was to investigate the effect of flow blockage in the core whereas that of SCTF Core-II test series was to investigate the effect of various parameters on core thermal hydraulics without any flow blockage present in the core.

1. Regulatory Issue

The SCTF was developed as part of the 2D/3D Program to address issues that arose during the hearings on ECCS performance in the early 1970's which led to the adoption of 10 CFR 50.46 Appendix K models. Specifically, SCTF Core-II studied heat transfer in the core during the reflood phase of a LBLOCA. The reflood heat transfer is a primary factor which determines how effectively the core can be cooled under LBLOCA conditions. There was a special concern about the heat transfer rate for a flooding velocity of less than one inch/sec. The SCTF Core-II offered the opportunity to study this and other parametric effects in a two-dimensional, full-size facility. The research to address LOCA issues was endorsed by NRR (as well as the Commission), including a request that the RES-developed computer code TRAC be verified with respect to its ability to calculate multidimensional flows (Enclosures A and B).

2. Conclusion

Subject to the restriction on application noted in (4) below, the results of SCTF Core-II tests showed that, as in other SCTF Core-I and Cylindrical Core Test Facility (CCTF) test series, decay heat was effectively removed by water-steam two-phase mixture generated during reflood, even for low flooding rates. A typical flooding rate was 6 cm/sec for the accumulator injection period and 2 cm/sec for the low pressure injection period. The heat transfer coefficient in the unquenched part of the core varied from 20 to 200 w/m^2-c (3.5 to 35 Btu/ft^2-hr-F) depending upon the distance from the quench front: the farther from the quench front, the lower the heat transfer coefficient. The overall heat transfer enhancement of two-phase flow versus steam-only flow is estimated to be a factor of 5 under typical reflood conditions above the quench front. This illustrates how conservative the steam only cooling requirement is for flooding rates less than one inch/sec as specified by Appendix K to 10 CFR 50. The hottest region of the core was usually about 80% toward the top of the core: i.e., about 3m from the bottom of the core. The top 20% of the core received a slightly better cooling because of the presence of additional liquid which had been de-entrained from the rising two-phase mixture at the core-upper plenum interface. The effects of major parameters on core cooling are:

A. Increased ECC flows did not affect the rate of liquid accumulation in the core which was essentially governed by the decay heat power and initial temperature levels. When supplied ECC was more than that needed for satisfying a given rate of accumulation and vaporization, the excess ECC was simply carried over to the upper plenum, hot leg, and the steam-water separator.

B. The shape of the initial temperature and core power distributions did not affect core cooling significantly. The core cooling was mainly affected by the level of average power and initial temperature. Local regions of high temperature and power drew additional liquid and hence received additional cooling through a chimney effect. The initial temperature level dominated the early part of reflood, whereas the power level dominated the latter part of reflood.

C. Separate gravity flood and forced flood tests showed very similar behavior for core cooling when other parameters were the same.

D. Countercurrent flow tests showed that the core was divided into two parts: liquid down flow region (2 out of 8 bundles) and two-phase mixture upflow region (6 out of 8 bundles). These tests showed that the liquid down flow was much more than the amount predicted by the small-scale countercurrent-flow-limit (CCFL) data.

3. Regulatory Implications

The SCTF Core-II tests results served as a major source of data used in revising 10 CFR 50.46 and Appendix K to 10 CFR 50 (ECCS rule) as promulgated in October, 1988. Further regulatory actions are not needed.

4. Restriction on Application

The SCTF is a low pressure test facility which was operated at less than 6 bar. In addition, there are other facility limitations such as an unrealistic square downcomer, a narrow, oval-shaped hot leg, and the excessive influence of the vessel wall. These factors must be considered before the SCTF results are applied to a PWR. Usually, TRAC or a similar computer code must be utilized for relating SCTF results to the full scale PWR.

5. Unresolved Questions

There are no unresolved questions with respect to the regulatory issue of core heat transfer during the reflood phase of a LBLOCA.

Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

Enclosures:
A. NRR Memorandum on Position on LOCA/ECCS Research Commission Papers
B. NRR Memorandum on Thermal-Hydraulic Research Needs
C. Research Information Report on the Slab Core Test Facility (SCTF) Core-II Test Series, Vol. 1 & 2
D. SCTF Core-II TRAC-PF1/MOD1 Analysis Summary