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

JAN 4 1990

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 164, "THERMAL-HYDRAULIC DATA BASE RELEVANT TO PLANTS OF THE BABCOCK AND WILCOX LOWERED-LOOP DESIGN"

References:

1. ALAB-708, 16 NRC1770, December 29, 1982.
2. Clarification of TMI Action Plan Requirements, NUREG-0737, November 1980.
3. Letter from H. R. Denton to R. B. Minogue, "Request for the Conceptual Design of a Facility for the Study of B&W and CE Integral System Characteristics," December 30, 1981.
4. J. Gloudemans and D. P. Birmingham, "MIST Program: Summary of Key Results," NUREG/CP-0097, Vol. 4, March 1989.
5. K. Almenas, et al., "Scaling of Integral Facilities at Reduced Pressures," MDNE/061589, June 15, 1989.
6. K. Almenas, et al., "Evaluation of Four MIST Atypicalities," MDNE/041089, April 10, 1989.
7. Letter from H. R. Denton to R. B. Minogue, "Request for Follow-on Program in the B&W Integral System Test Facility (MIST)," October 31, 1984.

This memorandum transmits results from research conducted in the Integral System Test (IST) program. IST includes the Multi-loop Integral System Test (MIST) facility at the Alliance Research Center in Alliance, Ohio, and the University of Maryland at College Park (UMCP) 2x4 Loop facility. This research provided thermal-hydraulic experimental data relevant to plants of the Babcock and Wilcox (B&W) lowered-loop design. MIST was jointly sponsored by the U.S. Nuclear Regulatory Commission, the Electric Power Research Institute (EPRI), B&W Owners Group (B&WOG) and B&W. The UMCP 2x4 Loop, a reduced-pressure and small-scale facility, was designed to address scaling atypicalities of the MIST facility and to provide data for code assessment.

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Regulatory Issue:

Following the Three Mile Island Unit 2 (TMI-2) accident, a number of regulatory issues concerning the design of the B&W reactors were raised. The effectiveness of feed and bleed and the boiler condenser mode (BCM) of natural circulation was challenged during the TMI-1 Restart Hearing conducted by the Atomic Safety and Licensing Appeal Board [1]. In BCM, heat is removed from the primary system through vapor condensation in the steam generator and the accompanying primary-to-secondary heat transfer. Clarification of TMI Action Plan Requirements (NUREG-0737) Item II.K.3.30 [2] required that small-break loss-of-coolant accident (LOCA) calculational models be compared to applicable data.

In response to NRR's request for integral system characteristics for B&W reactors [3], the NRC and industry formed a Test Advisory Group to make recommendations regarding the type of data base required to validate small-break LOCA models. The IST program was formed in 1983 to acquire the desired data. The primary experimental facility in the IST program is the MIST facility.

Although MIST is designed as a full-height and full-pressure integral experiment facility, it is still a scaled model of a B&W plant. Thus, it entails various design compromises such as an atypical downcomer. These design compromises are a potential source of distortion of some of the physical phenomena (e.g., variation of flow regimes in the hot legs) which in turn could lead to atypical transient behavior (e.g., premature interruption of natural circulation). The UMCP 2x4 Loop, a reduced-height and reduced-pressure, integral experiment facility employed an alternate design approach (e.g., a more typical downcomer) to assess the impact of some of the MIST design compromises on transient behavior.

Conclusion:

IST produced an integral experiment data base for natural circulation, small-break LOCA, feed and bleed, steam generator tube rupture, effects of non-condensible gases, and pump operations on small-break LOCA behavior [4, 5]. Key observations (1 to 6 for MIST, 1 and 7 for UMCP) are summarized below.

(1) Natural circulation was studied under varying degrees of loss of primary inventory. A key question about natural circulation was whether the BCM would remove decay heat effectively and depressurize the reactor coolant system. This mode of heat transfer was consistently observed.

(2) During small-break LOCA, heat removal from the primary system was further augmented by the steam venting from the upper plenum to the downcomer through the reactor vessel vent valves (RVVV). Adequate heat removal was observed in MIST tests for a wide range of primary boundary conditions (i.e., variation of break sizes from 5 to 50 cm^2, variation of break locations, and both full- and half-capacity HPI flows). In all cases tested, the MIST system depressurized and attained primary circuit mass equilibrium without uncovering the core.

(3) MIST results show that the feed and bleed technique can be utilized to cool the core and depressurize the primary system.

(4) For multiple simulated steam generator tube ruptures, the primary system depressurized rapidly due to tube-rupture discharge. BCM-like activity was observed between primary system break flow to the secondary side of the ruptured steam generator. For a smaller number of tube ruptures, the primary system depressurized by single-loop cooldown of the intact loop.

(5) The presence of non-condensible gases reduced BCM cooling, but did not prevent primary system cooldown and depressurization.

(6) Reactor coolant pump operation is advantageous during small-break LOCA. With forced flow, primary-to-secondary heat transfer is maintained longer and more energy is removed from the break. Therefore, the primary system pressure decreases more rapidly and the primary system refills more quickly.

(7) The comparisons of the experimental results from the two facilities indicated that the UMCP 2x4 Loop is able to simulate the thermal-hydraulic behavior observed in MIST. First, it reproduced the qualitative aspects of the flow modes. That is, it exhibited similar local flow regimes, flow regime transitions, the presence of both steady state and boiler-condenser natural circulation flows, and loop asymmetries [5]. Second, it reproduced the sequence at which these flow modes occur during an inventory depletion transient. Inventory scaling was used to estimate the quantitative aspects of the flow modes (e.g., duration, magnitude of pressure changes). A precise parameter to parameter mapping between the UMCP and MIST data is not implied and is, in fact, precluded by the stochastic nature of some flow mode transitions. However, key phenomena of inventory transients can be simulated and the effect of pressure on the characteristics of these phenomena is understood. Despite the differences between the design of the two facilities, similar thermal-hydraulic characteristics were observed. The MIST design atypicalities do not affect the expected thermal-hydraulic behavior during a small-break LOCA [6].

Regulatory Implications:

The MIST and the UMCP 2x4 Loop experimental data provide a sufficient small-break LOCA data base to satisfy the requirements of NUREG-0737. The integral system data is self-consistent, comprehensive, and suitable for benchmarking computer codes used to calculate B&W plant transients. Such benchmark calculations for MIST were performed and are in good agreement with experimental data. The data, as well as code calculations, show that various methods, such as feed and bleed and BCM, are effective modes of decay heat removal in a B&W plant during a small-break LOCA.

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Restrictions on Applications:

The scaling evaluation has shown that key thermal-hydraulic behavior (e.g., BCM) observed in these facilities can be expected to occur in full scale B&W plants of the lowered-loop design. However, these test facilities are scaled models of a B&W lowered-loop nuclear steam supply system. As such, various scaling atypicalities in simulating a plant were required. Hence, these data should not be applied directly to a full scale plant. Rather, validated computer codes (TRAC-PWR, RELAP5) should be used to calculate plant small-break LOCA. The requisite code validation was performed as part of the IST program.

Further work:

At the request of NRR [7], additional testing was performed in the MIST facility to obtain data for: small-break LOCA without high pressure injection; station blackout; and examining scaling questions. Analysis of these tests is expected to be completed by the end of 1989. Additional experiments are being performed at UMCP to further test the scaling concepts under more complicated boundary conditions, i.e., with HPI flow. Any new significant results will be reported in a future RIL.

Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

Enclosures:
(1) MIST Program: Summary of Key Results
(2) Evaluation of Four MIST Atypicalities

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RES Files
Subject File No. RIL # R-2115 164
Task No.
Research Request No.
FIN No.
NUREG No.
Docket No.
Rulemaking No.
Other
Return NRC-318 to RES, Yes ✓ No
NRC PDR

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