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

DEC 0 3 1982

MEMORANDUM FOR: Darrell Eisenhut, Director
Division of Licensing

FROM: Roger J. Mattson, Director
Division of Systems Integration

SUBJECT: BOARD NOTIFICATION CONCERNING A RECENT ACRS EVALUATION OF PWR FLOW BLOCKAGE

References: 1. TMI-1 Restart Appeal Board Notification, BN-82-71, containing letter from H. Denton, NRC, to H. Myers, congressional staff, "Dynamic Response of B&W Reactors to Small Break LOCAs.

2. Safety Evaluation Report, related to the operation of Midland Plant Units 1 and 2, NUREG-0793, Section 5.5, "Design Sensitivity of B&W Reactors", May 1982.

SUMMARY:
The purpose of this memorandum is to request that you inform all PWR Licensing and Appeal Boards of an evaluation by ACRS member H. Etherington titled "Flow Blockage by Steam During Natural Circulation in PWRs" and provided as enclosure (1). The Etherington evaluation discusses various mechanisms by which single phase natural circulation might be lost and regained. The feed and bleed mode of decay heat removal and the effect of high point vents in the B&W design on restoration of natural circulation are also discussed. The evaluation is primarily for plants with once through steam generators (B&W design), although some of the discussion relates to plants with inverted U-tube steam generators (Westinghouse and C. E. designs). The evaluation concludes that "the Committee (ACRS) may want to review the final disposition of this problem, and to be assured that the various possibilities (of core cooling) are reflected in sufficiently flexible and understandable operating procedures."

We recommend providing this information to the Boards due to recent interest in two phase natural circulation and the feed and bleed mode of cooling.

The staff is in general agreement with Mr. Etherington's evaluation. A similar evaluation was previously performed by the staff and documented in a letter which responded to questions from Dr. Henry Myers, Science Advisor to the House Committee on Interior and Insular Affairs. This

letter is attached to Board Notification BN-82-71 (Ref. 1). In this letter the staff also expressed concerns relating to the understanding of plant response by operators in the event of natural circulation flow blockage, and has recommended that the phenomena be investigated by integral system tests.

The staff is pursuing resolution of the requirement for integral systems tests with the B&W Owners as part of TMI-2 Action Items II.K.3.30 and I.C.1. (see NUREG-0737). The status of this resolution is summarized in a letter recently sent to all licensees with B&W designed reactors. A copy of this letter is provided for the board's information as enclosure (2).

The staff has reviewed the Etherington evaluation and our assessment is discussed in some detail below. We request that our assessment be provided to the licensing boards concurrently with the Etherington evaluation (enclosure 1) and the letter to the B&W Owners (enclosure 2).

Background:

Recent licensing proceedings (in particular the TMI-1 Restart Hearing) have focused on the ability of PWRs to remove decay heat in various modes of natural circulation when feedwater is available and by feed and bleed in the event of loss of all feedwater. License applicants have not relied on feed and bleed cooling in meeting the Commission's regulations, but the staff and applicants recognize that such capability is available at many PWRs as a defense in depth for events beyond the design basis.

As such, feed and bleed cooling is addressed in present emergency procedures and is included in the emergency procedure guidelines now under development. Natural circulation, both in single phase and two-phase modes (including boiler-condenser), is the primary mechanism for decay heat removal when the reactor coolant pumps are not operational and feedwater is available. Reliance on natural circulation to remove decay heat from the reactor system, both with and without a small break LOCA, has always been considered acceptable to the staff. Single phase (liquid) natural circulation has been demonstrated extensively in operating reactors, and two phase natural circulation including the boiler condenser mode, has been justified by test for inverted U-tube steam generator plants. Two phase natural circulation, including the boiler-condenser mode, has been shown to be effective by analysis for all PWR reactor types. In addition, auxiliary feedwater systems are sufficiently reliable to provide the required heat sink for satisfactory comformance to the General Design Criteria.

Staff Comments:

1. The evaluation by Mr. Etherington deals primarily with the time required to condense a steam bubble which might be trapped at the top of the hot legs of a B&W designed reactor and therefore affect the period of time in which natural circulation, and hence decay heat removal, was interrupted. The evaluation does not address core cooling as a result of natural circulation interruption. The question of core cooling in such a situation was addressed by the staff in BN-82-71 (reference 1). In that reference the staff

reported a similar evaluation of bubble condensation rates and concluded that the reactor core would be adequately covered and cooled regardless of the time required to condense the bubble and restore a liquid flow path between the vessel and the steam generators.

2. The Etherington evaluation postulates various heat transfer mechanisms for steam void condensation within the hot leg, assuming that the coolant loops are in a quiescent condition (little or no coolant flow). Bubble condensation times of between 3 and 65 hours are calculated, depending on which heat transfer mechanisms dominate the condensation process. The Etherington evaluation also makes note of a calculation performed by LANL using the TRAC computer code. The TRAC code predicted that the coolant loops would not be in a quiescent condition even in the presence of a steam bubble. Rather, it predicted an intermittent condition of slug flow causing rapid steam condensation. Using the RELAP-5 computer code the staff has also predicted slug flow in the coolant loops when steam voids were present.

   But the staff's conclusion on the safety of interrupted natural circulation does not rest on the TRAC or RELAP calculations. Rather the staff evaluated the consequences of both rapid and slow bubble condensation in Ref. 1. For the limiting assumption of an infinitely slow condensation rate (i.e., no condensation) the staff concluded that the reactor core would still remain covered with water and adequately cooled.

3. The staff does not believe that any current method of predicting steam void condensation rates has been adequately verified. The staff has concluded that additional data needs to be obtained using an integral system test facility scaled and geometically similar to the B&W reactor design. Appropriate test data has already been obtained for Westinghouse and CE designs at the LOFT and Semiscale facilities. The staff concluded in reference 1 that for B&W designs such data was needed for operator training and evaluation of emergency operation procedures but was not required to demonstrate the adequacy of core cooling.

4. In reference 1, the staff evaluated the consequences of steam voids trapped in the hot legs of a B&W reactor following a small break (i.e., stuck open PORV) which was subsequently isolated. The evaluation by Mr. Etherington postulates that voids might be formed by PORV or pressurizer spray actuation. We agree that pressurizer PORV or spray actuation*, when the primary system is at or near saturation conditions, is a mechanism by which voids might form and

*In this case, we assume this is the auxiliary pressurizer spray, which is not derived from the main reactor coolant pump flow. If this was normal pressurizer spray, which is derived from main reactor coolant pump flow, then this pump operation would also serve to sweep any steam voids into the steam generators where they would be condensed.

interrupt natural circulation. The staff also evaluated the effect of reactor system overcooling in producing void formation and the loss of natural circulation for B&W reactors in Ref. 2. This evaluation indicated that anticipated overcooling events should not result in the loss of natural circulation, and even the more severe steamline break events would only tend to block circulation in one loop.

5. The evaluation by Mr. Etherington states "It appears possible that there is no direct recovery to single-phase natural circulation from the boiler-condenser mode." The staff agrees with this statement in the sense that rapid void condensation predicted by computer codes has not been verified by integral system tests and, in fact, may not occur. However, recovery of single phase natural circulation is not required for successful mitigation of a LOCA as discussed below.

   Following a loss of coolant accident, the ECCS systems of PWRs are not designed to deliver enough water to the reactor system to completely refill it except for very small break sizes. When the system refills above the break elevation, the ECC water will spill out of the break and prevent the coolant level in the primary system from rising higher than the break elevation. However, because all primary system piping is at an elevation above the top of the core, the system will always refill to above the top of the core, thus assuring the core will be covered. By maintaining a water level above the top of the core, core cooling is assured by nucleate pool boiling heat transfer. This condition will maintain the maximum fuel cladding temperatures slightly above the coolant saturation temperature. Small break LOCA operator guidelines for B&W designed PWRs also state that it is not necessary to refill the reactor system following a LOCA in order to assure long-term core cooling.

6. The evaluation by Mr. Etherington states that a "one-inch vent line at the top of a U-bend could easily eliminate a steam void in a subcooled system as fast as makeup could be supplied. But venting a steam space in a saturated system without makeup could be an exercise in futility." We agree with these statements, but we note that the high point vents of PWRs are designed to vent hydrogen, not steam, in accordance with the requirements of 10CFR 50.44. They are designed to be small enough in diameter so that their failure will not produce a LOCA in accordance with Item II.B.1 of NUREG-0737. Most high point vent sizes are smaller than one inch i.d. If the high point vents were opened by the operator in an attempt to restore natural circulation while the primary system hot leg coolant was near to or at saturation conditions, the pressure in the vicinity of the open vent would decrease. This would cause some of the saturated liquid to flash to steam. The steam formed from flashing along with additional steam formed from boiling in the core, would replenish any steam removed from the hot leg U-bend by the vent. Opening of the hot leg high point vents would only aid in reestablishing natural circulation if opening the vent removes steam at a faster rate than it is generated and if the

volume occupied by the steam being vented was being replaced with liquid (i.e., the system was being refilled).

7. The staff agrees with Mr. Etherington's statement that natural circulation "Blockage by non-condensible gas remains as a low-probability occurrence". This statement is consistant with previous staff evaluations. (See NUREG-0565, NUREG-0611 and NUREG-0635.)

8. The evaluation by Mr. Etherington states that feed-and-bleed requires use of non-safety-grade components and is not an NRC requirement. We point out that at those plants which can feed and bleed with the safety valves, the safety valves are safety grade. In addition, at some plants, the PORVs do meet safety grade requirements. Thus, we believe a more appropriate statement would be "feed and bleed operation may rely on non-safety components.

Conclusions

Based on our assessment of Mr. Etherington's evaluation, we do not believe it contains any relevant material for new information per the criteria of Office Letter Number 19. Thus, we do not believe we are required to notify Licensing Boards of either Mr. Etherington's evaluation, or the staff's assessment of this evaluation. In fact, our assessment has concluded we are in general agreement with all of the points identified in Mr. Etheringtons evaluation, and that all of his concerns regarding the phenomena of natural circulation flow blockage have been previously identified by the staff and provided to the boards in Board Notification BN-82-71. However, due to the interest in natural circulation and feed and bleed cooling in recent licensing proceedings, we believe it is in the best interest of the regulatory process to make the licensing boards aware of this recent evaluation. We do not believe that these results adversely impact our present staff position regarding reliance on natural circulation or the validity of feed and bleed cooling as a defense in depth measure.

The staff is continuing to pursue with the B&W Owners the requirement for them to provide acceptable integral system experimental test data to aid in code verification and emergency operator procedure evaluation as part of TMI-2 action items II.K.3.30 and I.C.1 respectively.

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Enclosures:
1. Memorandum from R. Fraley ACRS to H. Denton NRR and R. Minogue RES, Transmitting Etherington Evaluation; November 10, 1982.

2. Letter from H. Denton NRC to W. Parker, Duke Power Company, November 16, 1982.

cc: See Next Page

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