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

MAR 1 1 1983

MEMORANDUM FOR: Darrell Eisenhut, Director, Division of Licensing

FROM: Roger J. Mattson, Director, Division of Systems Integration
Hugh Thompson, Director, Division of Human Factors Safety

SUBJECT: FOLLOWUP EVALUATION TO BOARD NOTIFICATION BN-83-21 FOR TMI-1

Reference: Memorandum, Mattson and Thompson to Eisenhut, "Board Notification", dated February 18, 1983

The reference memorandum requested that you notify licensing boards associated with reactors designed by Babcock and Wilcox of new and relevant information which had recently come to our attention. We also stated that we were in the process of evaluating this information to determine its safety significance and relevance.

We have completed our evaluation and have concluded that the information does not adversely affect our present conclusions regarding the ability of TMI-1 to achieve and maintain decay heat removal by natural circulation through the steam generators under transient and accident conditions. Our evaluations supporting this conclusion are provided in the enclosure. We request you foward this evaluation to the TMI-1 Appeal Board. Our generic evaluation for the remaining B&W designed plants will be issued in the near future.

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Enclosures: As stated

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## ENCLOSURE

### Background

On February 18, 1983, the staff issued Board Notification BN 83-21 This board notification identified information which had recently come to the attention of the staff that was potentially significant with respect to achieving and maintaining natural circulation in B&W-designed reactors. The genesis of the concerns was the staff review of the GPU-B&W lawsuit trial transcript. In this transcript, testimony by two individuals raised questions on two technical areas concerning natural circulation.

### The Issues

The details of the technical issues identified were discussed in BN 83-21 and are repeated here.

- During the trial, testimony by Dr. R. Lahey of Rensselaer Polytechnic Institute (RPI) and Dr. G. Wallis of Dartmouth College identified two concerns. These are (1) the adequacy of emergency operating procedures to assure that a sufficient condensing surface would be established in the steam generators under all design basis conditions for which decay heat removal by the steam generators was required and (2) the ability to establish an effective condensing surface at the elevation of the auxiliary feedwater sparger ring in light of new data which shows limited penetration into the tube bundle of feedwater entering the steam generator from the emergency feedwater sparger ring.

The first concern was raised by Dr. Lahey. It deals with procedures and relates to whether or not the operators have sufficient instructions and training to assure that they will raise the secondary level of the steam generator to 95 percent of the operating level under all conditions necessary to assure natural circulation. Following the TMI-2 accident, it was learned that the then current procedures instructed operators to raise the secondary level to 50 percent of the operating range. Under certain circumstances, it was possible to postulate that natural circulation would not be reestablished with the secondary level at 50 percent. Subsequently, it was determined that raising the level to 95 percent of operating range would assure natural circulation if the RCS was saturated. However, because of overcooling considerations, it is not desirable to raise the level to 95 percent for all cases of loss of forced circulation. Thus, specific plant circumstances dictate the appropriate steam generator level and the manner to achieve this level. The operating procedures and training to describe the correct actions are, therefore, important to the issue.

A discussion of this issue was presented in NUREG-0565 ("Generic Evaluation of Small Break Loss-of-Coolant Accident Behavior in Babcock and Wilcox Designed 177-FA Operating Plants," dated January 1980) and was provided in Attachment 2 to SN-83-21. A copy of the relevant sections of Dr. Lahey's testimony was provided as Attachment 3 to BN-83-21. Dr. Wallis' testimony was provided to the Appel Board and parties to the reopened TMI-1 restart proceding on March 8, 1983.

The second concern was raised by Dr. Wallis. It involves recent test data from the Alliance Research Center which shows that auxiliary feedwater entering from the sparger ring does not penetrate uniformly into the steam generator tube bundle but only contacts a small percentage of the tubes. This has the effect of lowering the elevation of the effective condensing surface in the steam generator. Previous analysis models assume good penetration of auxiliary feedwater spray into the tube bundle but recent B&W models account for the new data.

Staff Evaluation

1. EFW Spray Effectiveness

On February 23, 1983, the B&W Owners Regulatory Response Group (RRG) met with the staff to present information on the above two technical issues. Subsequent to this meeting, the owners group submitted a technical report, "Evaluation of SBLOCA Operating Procedures and Effectiveness of Emergency Feedwater Spray for B&W designed Operating NSSS," (Reference 1) which documented the information presented at the February 23, 1983 meeting. The staff has reviewed this report and our evaluation follows:

4. Effectiveness of Emergency Feedwater Spray

In the Once-Through-Steam-Generator (OTSG) design for the 177-Fuel Assembly plants, emergency feedwater enters the steam generator through seven nozzles located circumferentially around the OTSG shell and at an elevation just above the top tube support plate. This is shown in Figures 1 and 2, taken from the B&W report. Also shown on Figure 1 is the operating range for feedwater level (item 24).

Analysis models used by B&W and the staff have assumed that emergency feedwater injected at the sparger elevation would be uniformly distributed within the tube bundle and provide effective heat transfer to all tubes within the bundle. Data obtained from testing performed by B&W at its Alliance Research Center (ARC) shows however, that the emergency feedwater spray does not effectively penetrate the tube bundle providing uniform wetting and uniform heat transfer throughout the bundle. Rather, the emergency feedwater will only contact those steam generator tubes in the immediate vicinity of the injection nozzle. The emergency feedwater would then pool on the tube support plate and spread out, draining down the flow tube where the tubes penetrate the tube support plate. As can be seen from Figure 1, at least 6 tube support plates exist between the injection location and the top of the operating range. In Figure 3, B&W shows the emergency feedwater axial wetting profile measured in Oconee 1. This shows that as the emergency feedwater drains down the tube bundle, the tube support plates tend to spread the flow towards the center of the tube bundle. The wetting profile could be envisioned as an "inverted cone." The impact of this incomplete wetting of the tubes is that the heat transfer rates attributed to spray cooling above the secondary side pool level can be reduced from what they were originally, based on the 100 percent wetting assumption.

In the B&W report, data and data correlations are presented which allow the percent of tube area wetted above the secondary side pool level to be calculated as a function of EFW flow. In the following section, the reliance on EFW spray effectiveness will be discussed.

Subsequent to the TMI-2 accident, the staff investigated the possible causes for natural circulation not being established in TMI-2 once the reactor coolant pumps were shut off. In reference 2, it was postulated that natural circulation did not commence following RCP trip because the secondary side steam generator level was not high enough to establish a condensing surface which would allow natural circulation flow over the pump entrance. In references 3 and 4, the staff further explained and documented this concern and concluded that in order to assure natural circulation, (in particular boiler-condenser), the secondary side steam generator level must be raised to above the elevation of the pump inlet. B&W proposed raising the steam generator secondary level to 95 percent of the operating range in reference 5 (Licensee Exhibit 5). By raising the level to 95 percent of the operating range, a condensing surface that is above the elevation of the pump inlet and is sufficient to remove all decay heat in assured. By establishing a condensing surface above the pump inlet elevation, condensation of primary steam and the buildup of a condensate level on the primary side of the tubes sufficient to promote flow over the pump inlet is also assured. In addition, because the liquid levels in the core, downcomer, and steam generator are equalized due to the vessel vent valves, the 95 percent secondary level assured that a condensing surface will be established before core uncovery could occur. In other words, in order to assure that natural circulation (boiler-condenser) would commence and reestablish decay heat removal before core uncovery could occur, no credit for EFW spray effectiveness needs to be taken. The EFW spray could be postulated not to provide any heat transfer, as long as it contributes to the secondary pool inventory. Thus, while the effect of the reduced heat transfer due to the reduced penetration of EFW spray during a SBLOCA would be to change the degree of initial overcooling and thus the initial system pressure response, the overall conclusions regarding core cooling would not change.

Inherent in this conclusion however, is the assumption that the pool level on the secondary side of the steam generator is raised to 95 percent on the operating range in a timely manner following a SBLOCA. Presently, the EFW is automatically controlled to establish the level at 50 percent of the operating range. Operator action is required to raise the level from the 50 to 95 percent level. In order to estimate the time available for the operator to initate actions to raise the EFW level to 95 percent, analysis by

B&W in licensee exhibit 5 shows that for the largest break size for which steam generator heat removal would be required, (.01 sq ft.), boiler condenser heat transfer was calculated to commence after 25 minutes. Moreover, at the time boiler-condenser commenced, B&W analyses indicated 105,600 lbm would still remain above the core. If this amount of coolant were assumed to exit the primary system via the break (.01 sq ft.) as saturated liquid, it would still require at least an additional 35 minutes before core uncovery. This is a total of at least 60 minutes available to establish a condensing surface for the limiting break. If the level must be raised from the 50 percent to the 95 percent level and it takes approximately 1 minute to raise the level one foot*, then we estimated it would take approximately 12 minutes to raise the level to 95 percent. Therefore, there is estimated to be in excess of 13 minutes available for the operator to recognize the event and initiate filling of the secondary side of the steam generator with EFW to achieve the 95 percent level for the most limiting small break to establish boiler-condenser in the time period assumed in the B&W analysis. A still longer time would be available before core uncovery could occur.

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*This estimate is used by B&W and has been confirmed by the staff.

Figure 4, which is reproduced from Figure 3-3 of the B&W submittal, provides the results of mass and energy balances which demonstrate that even with reduced EFW penetration, and accounting for the plugged steam generator tubes at TMI-1, the EFW spray is still sufficient to remove decay heat.

The solid curve, labeled EFW spray, represents the point at which the overall heat transfer rates from EFW spray, combined with the primary to secondary temperature difference at the indicated RC pressure, can remove all of the decay heat at the indicated time. This curve is basically the energy balance requirement. The dashed lines represent the points at which the HPI flow can match the core boiloff at the prevailing pressure. The significance of this curve is that prior to any core uncovery, the break must uncover, and discharge steam. The source of the steam is the core boiloff; therefore the dashed line represents the point at which HPI flow will match break flow (the mass balance). The intersection of the two curves is the point at which both all decay heat can be removed by EFW spray and HPI can fully make up all mass loss through the break. For the TMI-1 case, these occur for all times beyond about 900 seconds for the 100% HPI case and beyond 1700 seconds for the 70% HPI case.* It is therefore only necessary to show that core

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*The 70% HPI case refers to 1 HPI train with a 30% reduction assumed to result from spillage of HPI out the break.

uncovery does not occur for any small breaks less than .02 square ft (i.e., those breaks which require the steam generators for heat removal). As previously shown, core uncovery cannot occur prior to at least 60 minutes, or 3600 seconds, which is in considerable excess of 1700 seconds as indicated above.

2. Emergency Procedure and Operator Training Adequacy

The staff's board notification BN-83-21, dated February 18, 1983, stated the importance of operating procedures and operator training in assuring that a sufficient condensing surface is established in the steam generators under all design basis conditions. The concern raised by Dr. Lahey is whether or not operators have sufficient instructions and training to assure that the secondary level of the steam generators is increased to 95 percent of the operating range in a timely manner for all conditions necessary to assure natural circulation.

Subsequent to board notification on this issue, the staff met with the licensee on February 23, 1983 to discuss the emergency operating procedures and operator training. Moreover, the staff selected emergency operating procedures to ascertain what instructions are provided relative to maintaining steam generator level. The review included TMI-1 procedures for responding to loss of coolant and inadequate core cooling and the procedure for natural circulation cooling. Our review concluded that the procedures provide specific instructions to increase steam generator level to 95 percent of the operating range under the following conditions: (1) reactor coolant pumps are tripped following a loss of coolant accident, (2) inadequate core cooling symptoms persist with no forced flow (whether or not after LOCA), or (3) voids occur during natural circulation and subcooling is not immediately reestablished.

Discussions with licensee representatives affirmed that the operators at TMI-1 have been trained in the use of these procedures. The staff did not review the training program in detail however, licensee representatives stated that operator training on use of emergency operating procedures included instructions to remain in the appropriate emergency procedure in use until the plant is in a stable condition unless the procedure specifically instructs the user to exit it. This further assures that the operator will not exit a procedure prior to establishing 95 percent level in the steam generator, if required.

Conclusions

The staff has evaluated information provided by the B&W owners group regarding the effect of reduced EFW penetration on decay heat removal capability at TMI-1. Base on this evaluation, we have concluded that for the design basis SBLOCA scenarios, EFW spray cooling need not be relied upon to assure adequate decay heat removal, and decay heat removal solely by primary steam condensation in the region of the secondary side pool, which is at an elevation of 95 percent of the operating range, is adequate. This conclusion assumes correct operator action within approximately 10 to 15 minutes to initate raising the steam generator level to the 95 percent level. For scenarios not normally considered in the design basis, including delayed EFW, credit for EFW spray cooling is relied upon to assure core cooling. Analyses by B&W show that after accounting for the reduced EFW penetration into the steam generator tube bundle, and after accounting for plugged tubes in the TMI-1 steam generators, the EFW spray cooling will still provide effective decay heat removal.

Based on staff review of the TMI-1 procedures and discussions with representatives of the licensee regarding operating training, the staff concludes that there is reasonable assurance that the operator will increase steam generator level to 95 percent of the operating range under the conditions for which it is necessary to establish natural circulation.

# REFERENCES

1. "Evaluation of SBLOCA Operating Procedures and Effectiveness of Emergency Feedwater Spray for B&W-Designed Operating NSSS," B&W DOC. ID. 77-1141270-00 dated February, 1983

2. Memorandum, B. W. Sheron to Z. R. Posztoczy "Pool Boiling -Condensation Natural Circulation In TMI-2," dated July 23, 1979.

3. "Generic Evaluation of Small Break Loss-of-Coolant Accident Behavior in Babcock and Wilcox Designed 177-FA Operating Plants" NUREG-0565 dated January, 1980.

4. B. W. Sheron, "Generic Assessment of Delayed Reactor Coolant Pump Trip during Small Break Loss-of-Coolant Accidents in Pressurized Water Reactors" NUREG-0623 dated November, 1979 (Appendix A).

5. Letter from J. H. Taylor (B&W) to R. J. Mattson (NRC) "Evaluation of Transient BEhavior and Small Reactor Coolant System Breaks in the 177-Fa Plant," Volumes I and II, dated May 7, 1979.

Figure 1 — NUCLEAR ONCE-THROUGH STEAM GENERATOR (OTSG)

(From Reference 1)

1. PRIMARY INLET NOZZLE
2. PRIMARY OUTLET NOZZLE (2)
3. FEEDWATER HEADER
4. FEEDWATER SPRAY NOZZLES (32)
5. FEEDWATER HEATING CHAMBER
6. "BLEED" STEAM PORT
7. SATURATED FEEDWATER
8. PORTS
9. GENERATING TUBES (15,500)
10. DEPARTURE FROM NUCLEATE BOILING
11. 100% QUALITY
12. SUPERHEATED STEAM
13. STEAM ANNULUS
14. STEAM OUTLET NOZZLES (2)
15. LOWER SHELL
16. UPPER SHELL
17. LOWER TUBE SHEET
18. UPPER TUBE SHEET
19. ADJUSTABLE ORIFICE
20. EMERGENCY FEEDWATER INLET
21. TUBE SUPPORT PLATES (15)
22. CYLINDRICAL BAFFLE
23. STARTUP RANGE LEVEL
24. OPERATING RANGE LEVEL
25. WIDE RANGE LEVEL

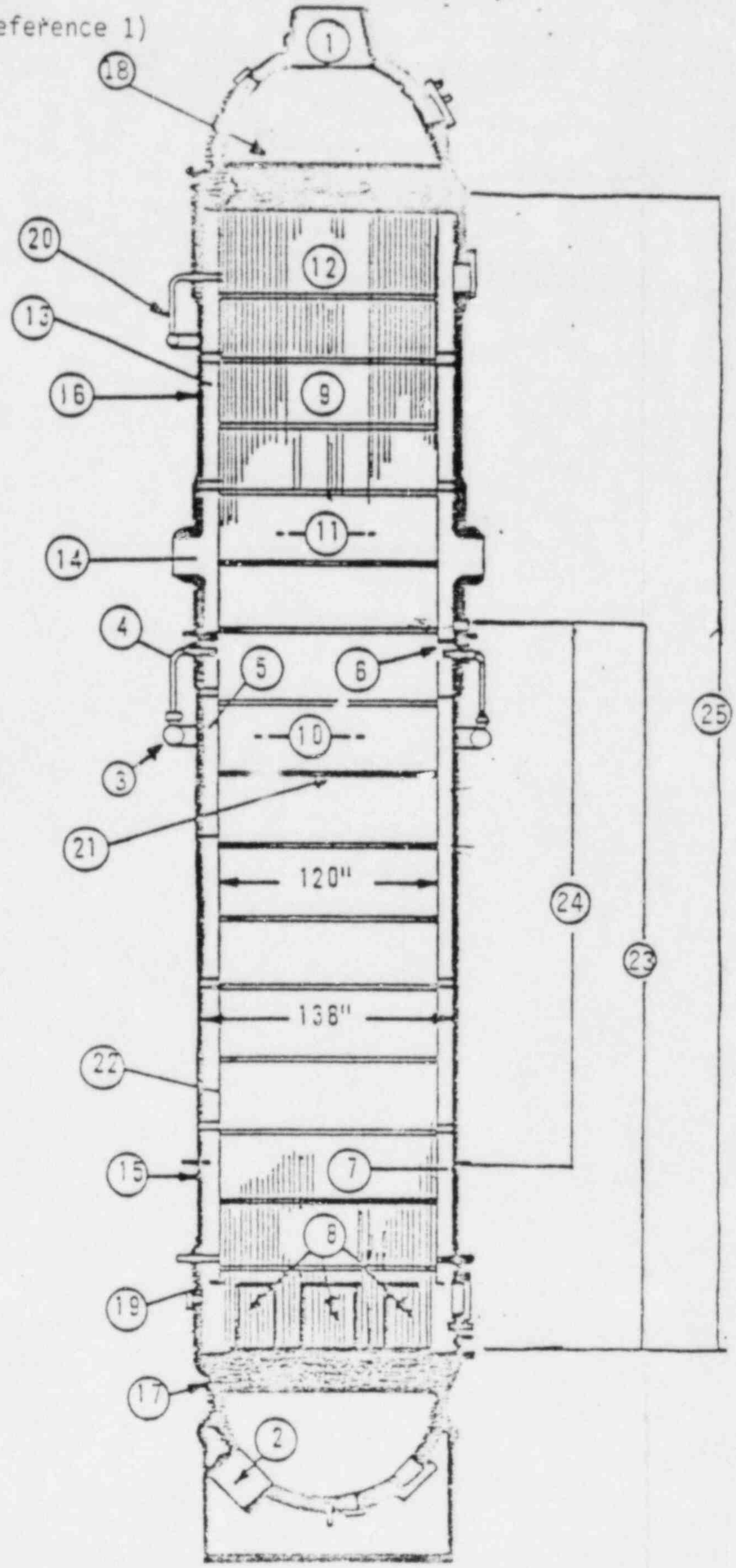

FIGURE 2 TYPICAL EMERGENCY FEEDWATER ARRANGEMENT

(From Reference 1)

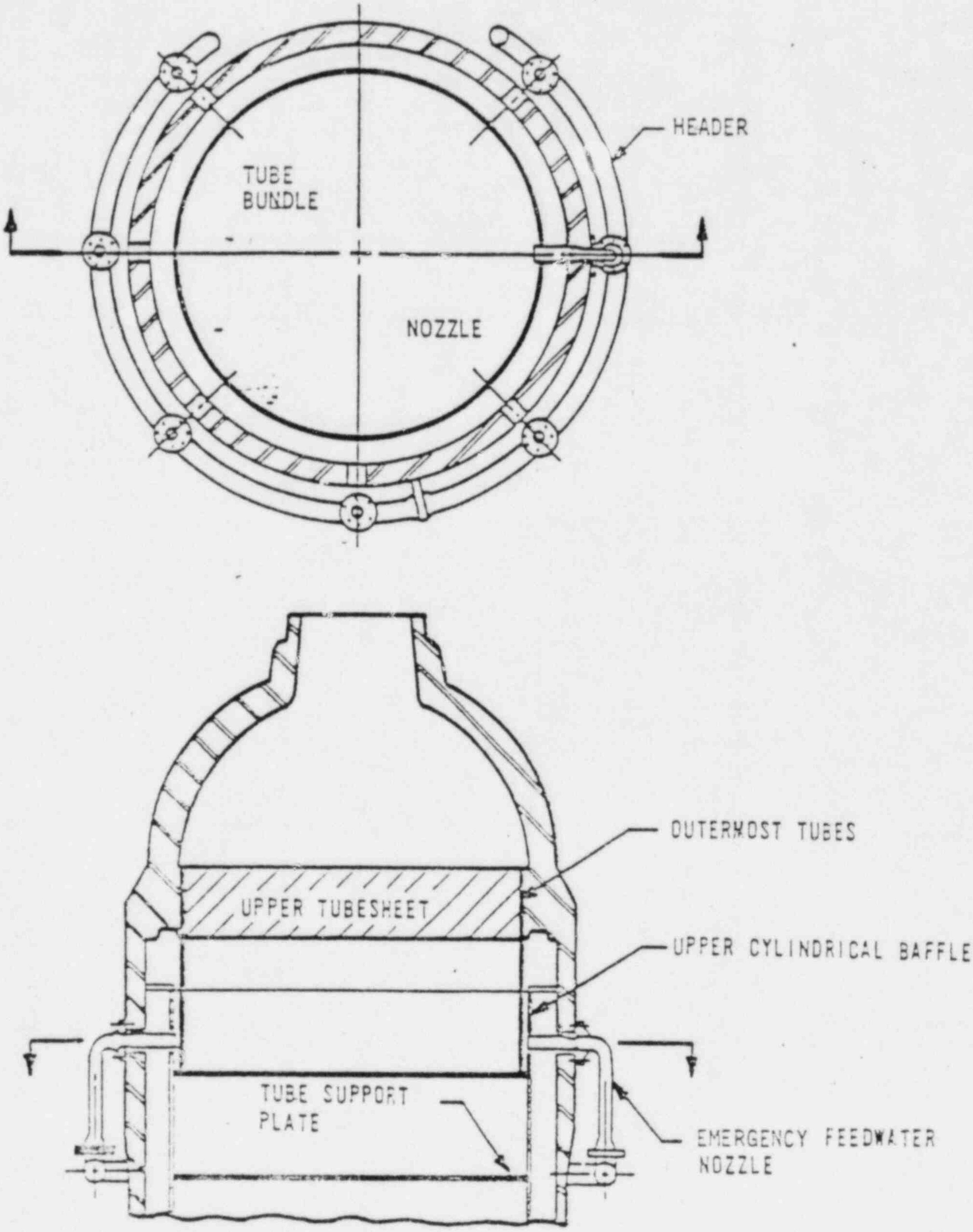

Figure 3 EFW AXIAL WETTING PROFILE
(OCONEE 1 - 1B OTSG)
(From Reference 1)

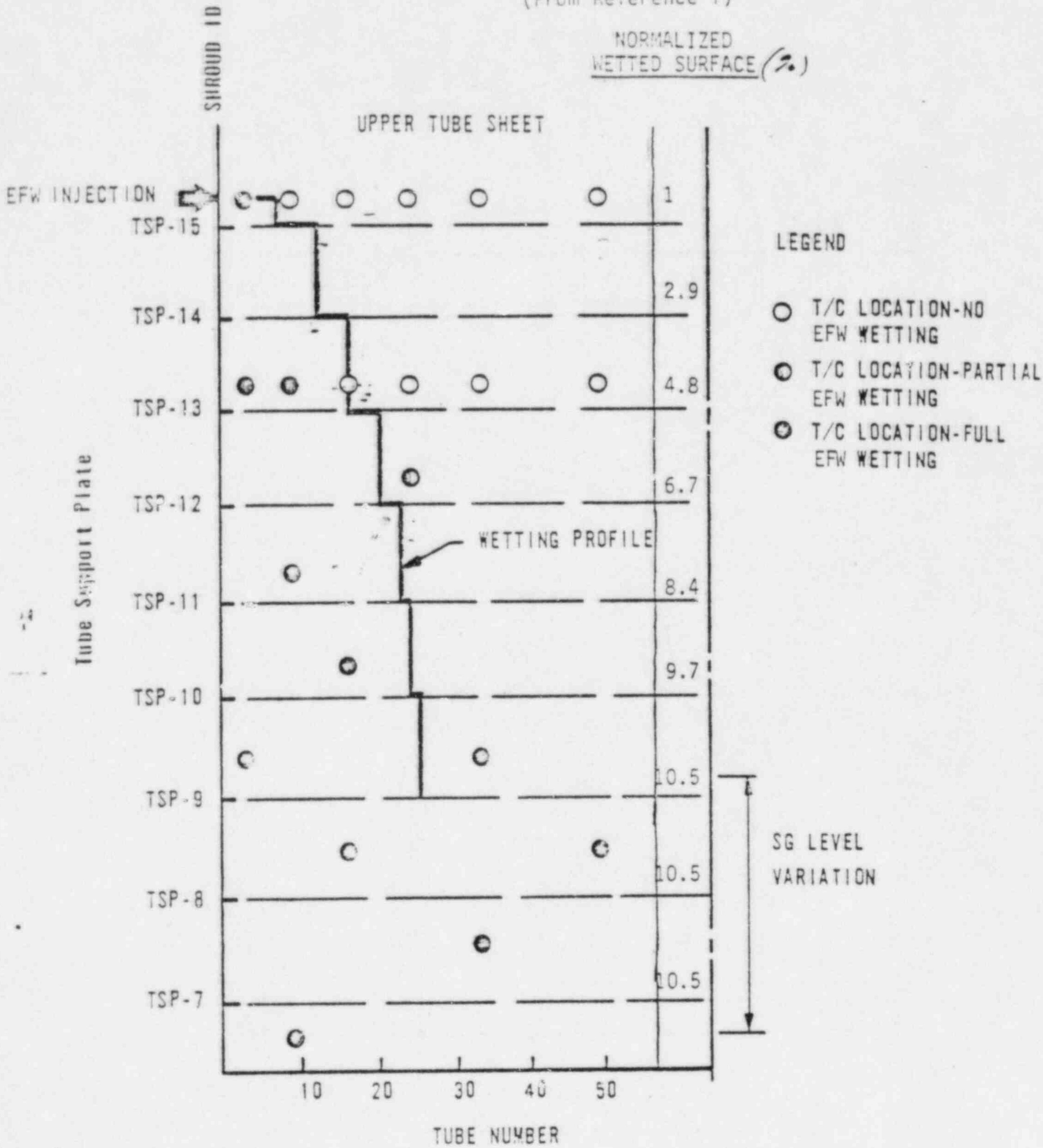

Figure 4

RELATIONSHIP OF HPI COOLING AND BOILER CONDENSER HEAT REMOVAL FOR TMI-1

(From Reference 1)