UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of	)	
	)	
METROPOLITAN EDISON COMPANY, ET AL	)	Docket No. 50-289
	)	(Restart)
(Three Mile Island, Unit 1)	)	

AFFIDAVIT OF WALTON L. JENSEN, JR. CONCERNING
THE APPEAL MEMORANDUM AND ORDER OF NOVEMBER 5, 1982

1. I, Walton L. Jensen, Jr., being duly sworn, state as follows: I am a Senior Nuclear Engineer in the Reactor Systems Branch, Division of Systems Integration, Office of Nuclear Reactor Regulation. A copy of my professional qualifications is attached.

2. In its Memorandum and Order of November 5, 1982 the Appeal Board stated its tentative views that neither the boiler-condenser mode of natural circulation nor feed and bleed have been demonstrated on the record as viable means of removing decay heat at TMI-1. The Appeal Board also stated the tentative opinion that the assignment of a dedicated operator to control the emergency feedwater system together with the installation of the high point vents in the hot legs would ensure core cooling by natural circulation during the interim before the emergency feedwater system is modified to full safety-grade status at the next refueling outage.

The Appeal Board requested that the parties provide comments on the above proposals. The purpose of this affidavit is to provide comments in two areas. (1) the adequacy of the record in demonstrating that boiler condenser natural circulation is a viable means of removing core decay heat and (2) the benefit of hot leg vents in restoring single phase natural circulation following a small break LOCA if boiler condenser natural circulation is not effective in removing decay heat.

3. Boiler-Condenser Natural Circulation

Boiler-condenser natural circulation is a process by which steam produced by boiling in the core of a nuclear reactor following a small break LOCA would be condensed in the steam generator tubes. The process requires only that a condensing surface be present which is cooled by feedwater and that the core be covered. Boiler-condenser natural circulation involves basic concepts of heat transfer which have been utilized by engineers for years and which are well understood. The boiler-condenser mode of natural circulation is relied upon to remove decay heat from the reactor system in the small break LOCA safety analyses for all pressurized water reactors.

Following extensive testimony, the TMI-1 Restart Licensing Board concluded that both licensee and staff presented evidence that the boiler condenser mode is a reliable method of heat transfer (PID at ¶ 621). Since the Licensing Board issued its decision, the staff has cited additional supporting evidence on the effectiveness of boiler-condenser natural circulation in Board Notification BN-82-71 dated July 27, 1982. On page 10 of that document the staff referred to recent tests at the LOFT and Semiscale facilities which demonstrated boiler condenser natural circulation to be effective for U-tube steam generators. The steam generator tubes at TMI-1 are straight rather than U-shaped; however, the same basic heat transfer mechanisms (condensation of primary system steam, conduction of heat through the steam generator tube walls, and removal of heat by feedwater on the secondary side) would occur regardless of whether the steam generator tubes were straight as in TMI-1 or U-shaped as in LOFT and Semiscale.

4. While the staff has concluded that additional experimental data is necessary to confirm the predictive capability of the computer codes for B&W designed plants, this need does not contradict our original conclusion on the efficacy of boiler condenser natural circulation. This is because the experimental data requirements pertain to our need to understand the detailed realistic system response (including man-machine interactions) associated with small breaks and other transients and accidents. For example, during the transition from single phase natural circulation to boiler-condenser natural circulation, the interruption of natural circulation may produce a pressure increase. Understanding of the hydraulic stability of the system during this transition would be useful to the operators for diagnosis of symptoms. However, the uncertainties associate with this transition do not affect our finding that for B&W designed plants a condensing surface will eventually be exposed in the steam generators, and establish the boiler condenser mode of natural circulation, before the core could become uncovered for the design basis response to certain small break LOCAs.

8. Hot Leg Vents

The operation of vents in the hot leg high points is both unnecessary and ineffective for the purpose intended by the Appeal Board, which we understand is to vent steam from the hot legs following a SBLOCA for the purpose of reestablished single phase natural circulation. The vents might, however, be beneficial in recovering single phase natural circulation from a condition of prior operation in feed and bleed or boiler-condenser natural circulation (see Jensen presentation to Appeal Board of 9-1-82 TR 307-310). In this case, steam trapped in the hot leg U-bends would be vented in order to enhance the refilling of the system with subcooled water. Hot leg venting when the primary system was saturated would probably not enhance the restoration of natural circulation since the depressurization associated with vent opening would cause more water to flash to steam and replenish the steam exiting the vents. However, recovery of single phase natural circulation is not necessary at TMI-1 to adequately cool the core for loss of feedwater/small break LOCA events. This is because for conditions for which natural circulation could be interrupted, the core would still be covered with water as discussed below.

9. The hot leg vents at TMI-1 are designed to remove noncondensable gases from the reactor coolant loops in accordance with 10 CFR 50.44. They are designed to be sufficiently small so that their failure will not produce a LOCA, as required by NUREG-0737, Item II.B.1. Because their venting capability is so small, they are not capable by themselves of sustaining feed-and-bleed cooling of the core.

10. Following a loss-of-main-feedwater event at TMI-1 for which the emergency feedwater system is automatically actuated, the reactor could be cooled and depressurized in single phase natural circulation without operation of the hot leg vents since no steam voids would form in the coolant loops. Following a loss-of-main-feedwater event at TMI-1 with delayed emergency feedwater actuation, decay heat would cause the reactor system to pressurize so that the safety valves would open in the first 3 minutes. Between three minutes

and fifteen minutes, the discharge from the safety valves would be liquid. After about fifteen minutes, the water in the reactor system would be heated to the boiling temperature corresponding to the safety valve setpoint pressure. At that time, boiling in the core would produce steam which would have to be removed by the safety valves. The pressurizer safety valves provide adequate venting capability for feed-and-bleed operation. However, since the pressurizer is connected to one hot leg approximately 35 feet below the top of the hot leg U-bend, steam above the pressurizer connection could not be readily removed during feed-and-bleed operation. If the vents were open, this steam trapped at the top of the hot legs would be vented. The reactor system safety valve setpoint is about 2500 psig. At that pressure, the total flow capacity of both hot leg vents (0.5 inches ID) is estimated to be about 15.0 lb/sec. The following table provides the steaming rate from the core at 15 minutes and 1 hour following reactor trip. The core steaming rate would decrease with time since the decay heat generation rate would decrease. When the steaming rate decreased to within hot leg vent relieving capacity, refilling of the reactor system could begin provided makeup water (HPI) were available to replenish the steam which was vented. The core steaming rate would be reduced if cool HPI water were injected into the core and the table includes the effect of operating one and both HPI trains.

	CORE STEAMING RATE IN LB/SEC		TIME WHEN SYSTEM REFILL CAN BEGIN USING VENTS ONLY TO REMOVE DECAY HEAT
	@ 15 MIN.	@ 1 HR.	
1 HPI	85	30	3.3 hours
2 HPI	27	0	33 minutes

11. The reactor system could begin to be refilled at the time indicated in the last column of the above table. An additional hour might be required to vent sufficient steam so that complete refill could be accomplished. When the reactor system was refilled with subcooled water by relieving steam using the hot leg vents and by adding makeup water, single phase natural circulation could be established. The final establishment of single phase natural circulation would require that feedwater, either main or emergency, be available. Refilling the reactor coolant system would require that the High Pressure Injection (HPI) also be operable.

12. In summary, the staff concludes that hot leg vents would be effective in promoting refill of the primary system with subcooled water so that single phase natural circulation could be established only long after the loss of feedwater event, if HPI and feedwater were available. If feedwater were available, it would provide for heat removal in the boiler-condenser natural circulation mode long before the primary system could be refilled. Similarly, if HPI were available, it could be used for feed and bleed cooling. Either of these cooling modes could effectively remove decay heat from the primary system long before single phase natural circulation would be reestablished.

The hot leg vents would not in themselves establish single phase natural circulation in a timely manner. They would, however, aid in refilling the primary system with subcooled water following previous operation in the boiler-condenser natural circulation mode or feed and bleed. Recovery of single phase natural circulation is not necessary at TMI-1 following a loss of feedwater event with delayed emergency feedwater actuation. Analyses by B&W have indicated that the reactor system can be cooled and depressurized in boiler-condenser natural circulation even if emergency feedwater actuation were delayed for as long as 20 minutes.

13. The above discussions assumes the absence of a break in the reactor system If a break were assumed, in addition to loss of feedwater and delayed emergency feedwater actuation, the loss of coolant flow out the break would prevent the reactor system from being refilled except for very small break sizes. Natural circulation cooling would not be required, however, for break sizes of .02 ft^2 and larger since the break size would be large enough to remove all decay heat. For smaller break sizes, if steam generator cooling were unavailable, the reactor system would pressurize to the safety valve setpoint of 2500 psig. At that pressure, a break size of .0033ft^2 (1 HPI pump available) or .0066ft^2 (2 HPI pumps available) would cause sufficient mass loss so that the reactor system could not be refilled. Refill of the reactor system is not necessary to prevent core damage for small break LOCAs. Analyses performed by B&W have indicated that core uncovery can be prevented for small break sizes of 0.02 and smaller, even if actuation of emergency

feedwater for boiler-condenser natural circulation is delayed for as long as 20 minutes.

14. In summary, refill of the primary system to establish single phase natural circulation following a small break LOCA for which boiler-condenser natural circulation was not available would be effective only for very small break sizes (less than $.0066ft^2$). The operation of the hot leg vents would have little effect on LOCA events larger than break sizes of $.0066ft^2$, since the system could not be refilled. The vents could aid in refilling the reactor system for very small break sizes when the reactor core steaming rate decreased to within the hot leg vent removal capability, as discussed in paragraph 10.

15. The establishment of boiler-condenser natural circulation is not required for break sizes of .02 ft^2 and larger. or smaller break sizes, analyses by B&W (which have been audited by the staff) indicate that boiler-condenser natural circulation will be effective to remove heat from the reactor system. Refill of the reactor system is not necessary following a small break LOCA since the system can be cooled and depressurized by the combination of ECCS flow, break flow and boiler-condenser natural circulation. Small break LOCA procedures for TMI-1 do not require that the reactor system be refilled.

16. Analyses by Babcock and Wilcox audited by the NRC staff have indicated that the reactor system can be adequately cooled and depressurized in the boiler-condenser mode of natural circulation for conditions when the reactor system is highly voided. Analyses by LANL, using the advanced TRAC computer code, have indicated that in the absence of a break, the reactor system would be refilled and any steam bubble contained in the reactor system would be

condensed by incoming HPI water and steam generator cooling. Single phase natural circulation was calculated to be established without vent operation. In the case of a break size sufficiently large so that the reactor system could not be refilled, the TRAC code calculated that the reactor system would be cooled and depressurized by heat removal from the break and by HPI flow even in the absence of natural circulation. These calculations are discussed in BN-82-71. In that same document, the staff evaluated the possibility that steam voids contained in the reactor system hot legs might not rapidly condense in the event of a break which had been subsequently isolated. For this condition, in which the steam condensation rate of the bubble is assumed to be low, refilling of the system would only serve to compress the steam bubble. If the steam bubble could not be compressed to a sufficiently small volume such that the hot leg liquid level would rise above the hot leg U-bend and produce a flow path to the steam generator, then natural circulation would not be reestablished. In this case, the system pressure would continue to rise to the safety valve setpoint and a phenomenon similar to feed and bleed would occur.

As the bubble was condensed by heat transfer to the liquid below it in the hot leg as well as to the coolant piping, the HPI being injected would displace the volume of condensed steam and raise the level of coolant in the hot leg. Several hours might be required for this process. Once a sufficient amount of steam condensed such that hot leg coolant could flow over the U-bend and establish single phase natural circulation, the system pressure would decrease, closing the safety or relief valve. If the voids grew in size from steam production in the core, boiler-condenser natural circulation would be established. The conclusion from all the above analyses and evaluations is that the core would remain covered and cooled. This is because the region for which natural circulation could be interrupted by steam voids is well above the top of the core. If conditions exist in the reactor system which cause steam voids to increase in size boiler-condenser natural circulation would ultimately be established if required for reactor system cooling. If the steam voids decrease in size, single phase natural circulation would ultimately be established. In any case, the staff concludes the reactor core will be adequately protected at TMI-1.

Walton L. Jensen Jr.

Walton L. Jensen, Jr.

Subscribed and sworn to before me
this 22nd day of November, 1982

Patricia J Noonan

Notary Public

My Commission expires: July 1, 1986