UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
SACRAMENTO MUNICIPAL UTILITY DISTRICT	)	Docket No. 50-312 (SP)
	)	
(Rancho Seco Nuclear Generating Station)	)	

NRC STAFF TESTIMONY OF PAUL E. NORIAN ON NATURAL CIRCULATION
(Board Question CEC 1-2)

Q1. Please state your name and position with the NRC.

A. My name is Paul E. Norian. I am Section Leader of the Systems Analysis Section, Analysis Branch, Division of Systems Safety. I have held this position since 1975 and am responsible for supervising the review of reactor vendor transient and LOCA analysis methods, the improvement of NRC analysis methods used in related accident analyses, and the performance of staff audit calculations for transients and LOCAs. From June through December 1979, I was assigned to the Bulletins and Orders Task Force as a member of the Analysis Group. I served as Alternate Group Leader and coordinated the reviews of small break loss-of-coolant accidents (LOCA) and transient analyses submitted by the vendor owner's groups since the Three Mile Island accident.

Q2. Have you prepared a statement of professional qualifications?

A. Yes. A copy of the statement has been presented with other testimony in this proceeding.

Q3. Please state the purpose of this testimony.

A. The purpose of this testimony is to respond to Board Question CEC 1-2 which reads as follows:

> CEC 1-2 Can poor understanding of natural convection in the Rancho Seco system result in a situation that will lead to inadequate cooling despite the modifications and actions of Subparagraphs A-E of Section IV of the Commission's Order of May 7.

Q4. Please explain the concept of natural circulation (natural convection).

A. Natural circulation, or natural convection, is the process by which coolant is circulated in the primary system without the aid of pumps. Removing heat from the fluid (and increasing its density) at a higher elevation than the elevation at which heat is added (and decreasing its density) produces a net weight increase of the total fluid on the heat removal side of the primary loop (steam generator side) compared to the total fluid weight on the heat production side of the loop (core). Thus, similar to a simple U-tube in which more water is initially higher in one side of the U-tube than the other, the water will flow around the bottom of the loop in an attempt to equalize the weight of

water on both sides of the loop. Because heat is continuously produced and removed in a nuclear reactor, this attempt to equalize the weight of the fluid on both sides of the loop is also continuous and the resultant flow is called natural circulation.

A5. How is natural circulation established in the primary system?

A. Several modes of natural circulation can be established in the primary system. The different modes relate to whether the fluid is single phase (no voids) or two-phase (contains significant voids). The single phase mode is the normal condition that would occur following the tripping of the RC pumps during an operational transient. This mode has been experimentally verified during plant startup tests, and during reactor operation following RC pump trip. Also, the TMI-2 reactor core has been cooled under single phase natural circulation since May 1979.

The natural circulation of the primary system fluid can also occur under two-phase conditions. If the fluid contains only limited voids, the liquid with the entrained voids will continue to circulate around the system. As the primary system voids increase, the steam will tend to separate from the liquid and would eventually result in the core being covered with a boiling liquid pool. The steam generated is transported to the steam generator and condensed. The condensed liquid travels back to the core to replenish the liquid that is being converted to steam. The resultant flow is considered another mode of natural circulation.

The various modes of two-phase natural circulation have not been demonstrated experimentally. The staff recommends 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, that these modes be experimentally verified by December 31, 1980.

Q6. Under what conditions is natural circulation relied upon to cool the reactor core?

A. Natural circulation is relied upon to cool the core for the following two conditions:

a) Small break loss-of-coolant accidents with a break area equivalent to a 2-inch diameter pipe (0.02 sq. ft.) or less. For such breaks, the energy discharged through the break is not sufficient to remove the core decay heat. Therefore, natural circulation would be used to depressurize the primary system so that the core could be cooled in the residual heal removal (RHR) mode. For break sizes greater than approximately a 2-inch diameter pipe, the energy loss through the break is sufficient to remove the core decay heat so that the primary system will depressurize and core cooling with the RHR system can be established.

b) Any transient event that results in tripping of the reactor coolant pumps. The operating procedures now require that all reactor

coolant pumps be immediately tripped upon reactor trip and initiation of HPI caused by low reactor coolant system pressure.

Q7. Did operators at TMI-2 demonstrate a poor understanding of natural circulation in connection with the March 29, 1979 accident?

A. At this time, the staff cannot state whether the operators at TMI-2 demonstrated a sufficient understanding of natural circulation in connection with the March 28, 1979 accident. However, failure to establish natural circulation was largely the result of the large mass depletion (voiding) in the primary system as discussed in Question 11 below.

Q8. Did poor understanding of natural circulation contribute to the severity of the TMI-2 accident?

A. The understanding of natural circulation by the TMI-2 operators did not contribute to the severity of the accident. The understanding of natural circulation by the Rancho Seco operators is discussed in the response to Contention CEC 3-1. That response indicates that the Rancho Seco operators have a good understanding of natural circulation.

Q9. Does the low elevation of the steam generator at Rancho Seco relative to the reactor vessel prevent effective natural circulation?

A. The low elevation of the steam generator relative to the reactor vessel does not prevent effective natural circulation. The driving force for single phase natural circulation is provided by the difference in gravitational head between the hot and cold legs. The effective cold leg head is determined by the elevation of the region in the steam generator where the heat is removed. Since the auxiliary feedwater is sprayed into the steam generator near the top of the once through tubes, this region is near the top and determines the length of the effective cold leg. The length of the steam generator below the core is not significant under single phase conditions since there is a downward (SG tubes) and upward leg (pump suction pipe) which are at the same temperature, and the head from these portions of the loop cancel each other in the net loop force balance.

The elevation of the steam generator below the core can be significant if the steam contains a large amount of voids. As discussed in Question 11 below, the fluid level in the steam generator must be above the elevation of the reactor vessel inlet nozzle. Since the bottom elevation is below the core, a large volume of water is required to achieve this elevation. However, if this level is achieved, natural circulation will occur.

Q10. Can a situation be postulated where natural circulation could not be established?

A. Yes.

Q11. Describe that situation.

A. To achieve natural circulation in the Rancho Seco reactor, a fluid level in the steam generator tubes must be established above the level of the reactor vessel inlet nozzle. If this level is not maintained, the fluid will be trapped in the loop formed by the lower portion of the steam generator and the reactor coolant pump suction piping. It is also possible to interrupt natural circulation if the system contains significant non-condensible gas or steam such that the U-bends at the top of the hot legs are blocked.

Q12. What method of core cooling could be used in that event?

A. If natural circulation cannot be established, the core can be cooled in the feed and bleed mode. In this case, water is injected into the primary system by the high pressure injection system, and the core heat is removed through the pressurizer relief and safety valves. The cutoff head of the pump is above the pressure setting of the safety valves so that injection can continue even though the system is at high pressure.

Q13. On the basis of the above testimony, do you believe the reactor core at Rancho Seco could be adequately cooled in the event of a transient induced by a loss of main feedwater and/or turbine trip?

A. If a transient induced by a loss of main feedwater and/or turbine trip should result in tripping of the reactor coolant pumps, the core can be adequately cooled by means of natural circulation.