Southern California Edison Company

P.O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

February 8, 1982

Director, Office of Nuclear Reactor Regulation
Attention: D. M. Crutchfield, Chief
Operating Reactors Branch No. 5
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket No. 50-206
SEP Topics XV-10 and XV-15 (Additional Information)
San Onofre Nuclear Generating Station
Unit 1

By letter dated December 18, 1981, the NRC staff requested that we provide additional information regarding the subject SEP topics. This additional information is provided as the enclosure to this letter.

If you have any questions or desire additional information, please contact me.

Very truly yours,

R. W. Krieger
Supervising Engineer
San Onofre Unit 1 Licensing

Enclosure

A035
S 1/1

ENCLOSURE

SEP Topics XV-10 and XV-15
Additional Information
San Onofre Unit 1

NRC Request No. 1

TOPIC: XV-10, Boron Dilution

1. Please identify the time available for operator action to terminate an uncontrolled dilution following an alram (such as rod insertion limits) for the following modes of reactor operation.

   - Reactor at power
   - Reactor at hot standby
   - Reactor at cold shutdown

2. Please provide an evaluation of uncontrolled boron dilution, including available alarms and time for operator action with the reactor in the refueling or hot shutdown mode.

Response No. 1

The information regarding Boron Dilution which was provided in our letter dated July 1, 1981 was based on very conservative nuclear data for the initial core loading of the unit which resulted in an assumed reactivity insertion rate of one pcm per second. In order to respond to your Request No. 1, it was necessary to reanalyze the boron dilution event assuming more realistic dilution and reactivity insertion rates to establish meaningful operator response times. A complete evaluation of the event for all operating modes is therefore provided which includes a determination of all possible sources of unborated water and associated flow rates. In addition, since the Boron Dilution event becomes less severe with increasing core cycle, the event was analyzed using Cycle 8 nuclear data which will render this evaluation conservative with respect to future cycles.

The piping arrangement at San Onofre Unit 1 is such that there are 2 possible sources of unborated water which could be injected into the primary system. These two sources are the Chemical and Volume Control System (CVCS), and the Feedwater and Condensate System (FCS). In order to inject water from the FCS, it is required that at least two valve failures on the same source line be assumed. This situation is not considered credible and therefore this evaluation will only be concerned with the CVCS.

In order to examine the possibility and consequences of boron dilution through the CVCS, the following items are presented to:

1. Indicate that there is a single, common source of demineralized water to the Reactor Coolant System (RCS).

   Demineralized water is provided to the CVCS from the Primary Plant Make-up Tank (PPMUT). The operation of the Primary Plant Make-up pumps, which take suction from this tank, provides the only supply of demineralized water to the CVCS and then ultimately to the RCS. This tank and pumping arrangement is shown on P&ID 568776-21.

The discharge header of these pumps can deliver demineralized water to several destinations in the plant; however, only one line, 716-3"-HP, goes to the CVCS. (The CVCS is shown on P&ID 568767-21.) The remaining lines from the header cannot provide demineralized water to the RCS. If demineralized water is to be added to the RCS, at least one of the make-up pumps must be operated.

2. Establish and indicate the possible flow paths by which demineralized water is utilized within the CVCS and the purpose of these functions.

Make-up water supply to the CVCS branches off to four possible flow paths as follows:

<u>Path 1</u> The normal flow path in the CVCS is through the chemical blending device and is automatically controlled to maintain a flow of 45 gpm by FCV-1102A.

The borated water from the boric acid tank is blended with the demineralized water in the mixing device, and the composition is determined by the preset boric acid concentration of the Reactor Makeup Control. Using this system to make dilutions, the operator is limited to batch dilutions of a maximum of 10 cubic feet (approximately 750 gals). The batch integrator in this system closes valve FCV-1102A when the preset amount of water has been added. If additional demineralized water is desired, the control sequence must be repeated by the operator. The addition can be stopped at any time by manual operation of the stop switch on the operator's console.

Just upstream of FCV-1102A in this path, there is an alternate path through line 2056-2"-151N to either the Chemical Mixing Tank (Item C-34) or directly to the suction of the charging pumps. The Chemical Mixing Tank is used for batch addition of chemicals to the RCS and has a capacity of two gallons. The line to and from the Chemical Mixing Tank is a 1/2" line and is not capable of passing a significant flow rate. The line is normally closed by valves 345-1/2"-T42 and 348-1/2"-T42.

The other bypass of the blending device into the suction of the charging pumps is provided for two reasons: first, to provide an alternate path for blending boric acid and demineralized water; second, to provide a means for flushing the short section of line between CV-334 and the charging pump header. This 2" line is normally locked closed by valves 336-2"-X42D and 336A-2"-X42D.

<u>Path 2</u> Demineralized water is also used to backflush the Reactor Coolant Filter. When this flushing is being done, the normal letdown flow path would be bypassed around the filter and valves 224-3"-G42 in line 2036-3"-151R and 219-3"-T42 in line 2043-3"-151R would be closed. If, through some valving error, valve 224-3"-G42 were not closed, the flow from the makeup pumps would be delivered to the Volume Control Tank during the backflush period.

In the unlikely event that a valve into the letdown line is left open during the backflush of the reactor coolant filter, the gas space in the volume control tank could fill with unborated makeup water. The maximum storage potential of this tank is its total volume of 205 cubic feet (approximately 1550 gallons).

<u>Path 3</u> A third takeoff (line 895-2"-HP) from the reactor coolant makeup water supply is provided to the cross connection (line 2064-2"-HN1) between the suction of two transfer pumps (G-9A and G-9B). This flow path is used to fill the batching tank with demineralized water and is arranged so that either transfer pump could be used. This path would only be used in making up a new batch of 12% boric acid in the batching tank. Upon filling this tank (600 gallons) the valve is closed.

<u>Path 4</u> The fourth function of makeup water within this system is to backflush the boric acid filter. This is done through line 8010-1"-HP. This path is normally locked closed.

3. Demonstrate what the maximum flow capacity of demineralized water addition to the RCS is and its dependence upon operation of various pumps and flow paths.

In order for demineralized water to be added to the RCS during operation of the plant at pressure, either a charging pump (or pumps) or the test pump must be running in addition to the primary plant makeup pump (or pumps). (The shutoff head of the makeup pump is 125 psi and cannot deliver water directly to the RCS when the RCS pressure is greater than 125 psi.)

The principal charging line to the RCS is through the Regenerative Heat Exchanger through control valve FCV-1112. The charging flow enters the RCS in the cold leg of Loop A. During operation, water is also injected into the reactor coolant pump seals through each of the injection lines to the individual pumps. A portion of the seal water injection flow also mixes with the reactor coolant flow. The post accident recirculation lines branch off of the pump seal injection lines and are piped into each of the safety injection lines. The motor operated valves on these recirculation lines are normally closed and are used only for the recirculation function following a loss of coolant. The above points are the only paths whereby demineralized water can be introduced into the RCS.

The rate of addition of unborated makeup water to the RCS is limited to the capacity of the charging pumps or the test pump during normal plant operation. The charging pumps are capable of delivering approximately 125 gpm through the charging line when the plant is fully pressurized. During low pressure conditions in the RCS, when higher flows are possible through the charging line, the limiting makeup rate is determined by the makeup water pump characteristic and the resistance of the dilution flow path from the makeup pumps. In the very conservative case where these pumps deliver directly to the charging pump suction with all valves wide open and the RCS at atmospheric pressure, the limiting addition rate is less than 225 gpm for both makeup pumps and 195 gpm for a single pump. For totally unborated water to be delivered at this rate to the RCS, a charging pump must be operated and its flow controlled by FCV-1112 to prevent the pump from cavitating.

During refueling, with the charging pumps out of service, the maximum flow possible through the charging line from both makeup pumps is approximately 70 gpm assuming no-flow resistance through the charging pump.

4. Demonstrate: (1) the operator would have substantial indications that a water addition was occurring; (2) the time available for him to take corrective action; and (3) what corrective action he would take.

For each plant condition, the corrective actions to be taken are the same. They are to close the dilution path and start to borate the RCS using the RWST as a source. These actions can be met by:

1. Open valves MOV-LCV-1100B and MOV-LCV-1100D. This aligns the charging pump suction to the RWST.

2. Stop the primary plant makeup pumps.

3. Stop the boric acid transfer pumps, if operating.

4. Close MOV-LCV-1100C and MOV-LCV-1100E from the volume control tank.

All of these actions can be performed in the main control room.

The indications available to the operator and the time to take the above corrective actions differ for various plant conditions.

Refueling

During refueling, continuous mixing flow will be maintained through the reactor vessel by utilizing an RHR pump. The RHR flow enters through the cold leg on Loop A, flows around the annulus between the internals and the vessel, up through the core and out through the hot leg connection on Loop C. The charging flow mixes with the flow from the RHR loop and is circulated through the reactor. The valves in the seal water lines to the reactor coolant pumps will be closed during the refueling operation. The charging pumps will be lined up for addition of concentrated boric acid water. Any change in the boric acid concentration at this time would be made through the charging line under administrative control.

During refueling operations, the boron concentration (2500 ppm) in the refueling water is periodically sampled. This concentration is sufficient with the control rods to maintain the reactor approximately 10% shut down. During this period, detectors with audible count rates provide direct monitoring of the core.

If one were to hypothesize that both the primary makeup pumps were started and that the charging flow path were completely opened through the CVCS, a continuous dilution at 70 gpm could be initiated. The minimum water volume in the RCS at this time would be the 1800 ft^3 required to fill the reactor above the nozzles in order to assure mixing via the RHR loop.

Assuming complete mixing in the RCS, the rate of change of the boron concentration during dilution is described by the following equation:

$$M\frac{dC}{dt} = -WC, \tag{1}$$

where:

M = RCS mass
C = RCS boron concentration
W = charging mass flowrate of unborated water

The magnitude of dC/dt is maximized by maximizing W and minimizing M.

Assuming

W = constant equal to the maximum possible value,

and choosing

M = constant equal to the minimum value occurring during the boron dilution incident,

the solution of equation (1) can be written:

$$C(T) = C(o)e^{-T/t} \tag{2}$$

where:

T = time into the dilution event

t = M/W = boron dilution time constant

C(o) = initial boron concentration

C(T) = boron concentration at time T

The time required to dilute to the end of the event is given by

$$T = t \cdot \ln \frac{C(o)}{C_{end}}, \tag{3}$$

where:

C_{end} = end boron concentration

During this mode, the operator would be alerted to a dilution event by the following:

1. increase in the audible count rate from the in-core detectors
2. alarm from both primary plant makeup pumps operating (if both were operating)
3. indication of a charging pump operating (if it were)
4. flow indication on FI-1112 on the charging line
5. flow indication on FR-1102 if the dilution path were through line 2052-2"-HN1
6. alarm and flow indication from FIT-1102A if dilution were through 716-2"-151N
7. alarm on boric acid addition 5% below setpoint if dilution were through the chemical blend device and no boric acid were being added
8. volume control tank high level alarm if dilution were through line 2036-3"-151R and a charging pump were not running.

In addition, in order to dilute to a critical condition, more than 9400 gallons of demineralized water would need to be added to the RCS. This increase in RCS inventory would surely be detected by the operator.

Under the most extreme conditions, the operator would have more than 40 minutes as indicated in Table 1, to take action from the time the dilution started at which time he would receive the first audible alarms (pump start).

Cold Shutdown

The plant conditions for cold shutdown are similar to Refueling except that:

1. RCS volume is greater (5849 ft^3 or 43,477 gallons)
2. lower boron concentration (1240 vs. 2500 ppm)
3. most reactive control rod assumed to be stuck in the full out position.

Alarms and indications are similar to the refueling mode.

Under the most extreme conditions, the operator would have more than 75 minutes as indicated in Table 1, to take action from the time the dilution started at which time he would receive the first audible alarms (pump start).

Hot Shutdown

The plant conditions assumed for this analysis are:

1. BOL
2. ARI, except most reactive rod in full out position
3. K = 0.97

Alarms and indications for the operator are similar to those given in the discussion of Refueling.

Under the most extreme conditions, the operator would have more than 33 minutes as indicated in Table 1 to take action from the time the dilution started at which time he would receive the first audible alarms (pump start).

Hot Standby

The plant conditions assumed are:

1. BOL
2. ARO
3. HZP
4. K = 0.99

Alarms and indications for the operator are similar to those given in the discussion of Refueling except for numbers 1 and 8. In this condition, these would be no audible count rate and a charging pump would be running with suction aligned to the volume control tank.

Under the most extreme condition, the operator would have more than 15 minutes as indicated in Table 1 to take manual action before the reactor reaches criticality. The reactor could be made subcritical by borating the RCS as described above or by a reactor scram on:

1. high power (25%) (automatic)
2. Variable low pressure
3. high pressure (automatic)
4. manual (operator action).

The RCS boron concentration in the post-scram condition would be higher than the hot shutdown condition. Following the scram, the operator would have an additional 33 minutes before the reactor would return to critical (or a total of more than 49 minutes). Therefore, this operating condition is less severe than the hot shutdown boron dilution event. Moreover, the boron dilution event is less severe than the uncontrolled control rod withdrawal event.

Full Power

The plant conditions assumed for this analysis are:

1. BOL
2. ARO
3. Equilibrium Xenon

Under normal operating conditions, the reactor control system is in automatic. The control rods would be automatically inserted to maintain a constant Tave. Since the Reactor Control System can decrease reactivity faster than dilution can add reactivity, the reactor would remain at 100% power. The operator would be alerted to the dilution event by:

1. high power alarm 106% (in manual)
2. both charging pumps operating
3. both primary pumps operating
4. rod insert (in automatic)
5. same demineralized water flow indications and alarms as in Refueling
6. increasing RCS pressure (in manual)
7. increasing RCS level or letdown flow.

In manual mode and under the most extreme conditions, the reactor would scram on high power (109%) in approximately 3.5 minutes. An additional 33 minutes or more of uncontrolled dilution would be required to return to criticality. Therefore, assuming reactor scram to be the first alarm, there would be 33 minutes for operator action in the worst case.

REFERENCES:

1. Letter, D. M. Crutchfield, NRC, to R. Dietch, SCE, Request for Information, December 18, 1981.

2. Letter, K. P. Baskin, SCE, to D. M. Crutchfield, NRC, SEP Topic XV-10, July 1, 1981.

3. P&ID 568767-21, Chemical and Volume Control System

4. P&ID 568776-21, Misc. Water Systems

Table 1

Inadvertent Boron Dilution Event Data

Plant Condition	Initial Boron Conc. (ppm)	Final Boron Conc. (ppm)	Duration of Event for Various Charging Flows (min.)			
			45 gpm	90 gpm	195 gpm	225 gpm
Refueling(2), ARI, BOL, K=0.90(3)	2500	1240	209.6	104.8	48.4	41.9
Cold Shutdown ARI(1), BOL	1840	1240	383.5	191.7	88.5	76.6
Hot Shutdown ARI(1), HZP, K=0.97, BOL	1250	1050	169.4	84.7	39.1	33.8
Hot Standby ARO, HZP, K=0.99, BOL (4)	2040	1885	76.7	38.3	17.7	15.3
100% Power BOL ARO, Equilibrium Xe (4)	1442	1415 (109% power)	18.3	9.1	4.2	3.6

(1) All rods inserted, except the most reactive rod is assumed stuck in the full out position.

(2) In the refueling mode, the RCS may be partially drained to a minimum volume of 1800 feet^3 instead of 5849 feet^3.

(3) The actual maximum charging flow in this mode is 70 gpm with charging pumps locked out.

(4) The times listed for this condition are the times to reach a safety system set point and produce a reactor scram, given no other operator action or automatic system response. The reactor would be in the Hot Shutdown condition following a reactor scram. The times listed for operator action in Hot Shutdown would then be in addition to the time to scram.

NRC Request No. 2

TOPIC: XV-15, Inadvertent Opening of a Pressurizer Safety/Relief Valve. Please provide the results of your DNBR calculation for this event.

Response No. 2

The inadvertent opening of a pressurizer safety/relief valve was analyzed in the report entitled, "Study of Small Loss of Coolant Accidents for the San Onofre Nuclear Generating Station, Unit 1," dated February 29, 1980 which was submitted to the NRC by letter dated July 28, 1981. This analysis was performed to demonstrate that such breaks are not limiting in terms of peak clad temperature. The results indicated the plant achieves a stable condition and the core remains covered during the transient with no voiding. As a result, the clad temperature remains very near the system saturation temperature. The analysis was performed using approved Appendix K models and assumptions. No detailed DNB evaluation has been performed; however, DNBR less than 1.30 is not expected based on analyses performed for other Westinghouse plants and similar protection provided by the San Onofre Unit 1 reactor protection system.