

Southern California Edison Company



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

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K. P. BASKIN
MANAGER, NUCLEAR ENGINEERING
AND LICENSING

TELEPHONE
(213) 572-1401

Director of Nuclear Reactor Regulation
Attention: D. L. Ziemann, Chief
Operating Reactors Branch No. 2
Division of Operating Reactors
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket No. 50-206
Steam Generator Water Hammer
San Onofre Nuclear Generating Station, Unit 1

As part of the NRC's review of the occurrence of steam generator water hammer, you requested additional information by letter dated September 12, 1979. Responses to your request are provided as Enclosure I to this letter. Enclosure I indicates: 1) that uncovering of the steam generator feedring has occurred often during unit shutdowns, trips and startups; 2) procedural changes have been implemented at Unit 1 to minimize the occurrence of conditions conducive to steam generator water hammer; and 3) in the event a water hammer is detected, the feedwater piping outside containment will be visually inspected.

A description of the available information concerning the three feedline water hammer events reported to the NRC to date is provided as Enclosure II. These events were previously described in our July 14, 1975, December 27, 1977 and July 3, 1979 letters. As indicated in Enclosure II only events 1 and 3 were actually observed to be feedline water hammers. Event 2 is the discovery of damaged feedline and steamline supports inside containment which was first speculated to be caused by water hammer but later determined to be due to improper design of the supports.

Based on the number of feedring uncovering events and the fact that there have only been two observed feedline water hammers, it is concluded that the occurrence of feedline water hammer at San Onofre Unit 1 is a low probability event. Modification of the steam generators at San Onofre Unit 1 is not considered warranted at this time.

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Mr. D. L. Ziemann

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Notwithstanding the above, since past water hammers have proved to be of sufficient magnitude to damage piping components and despite our conviction that further water hammers are of low probability, a program will be initiated to evaluate the potential magnitude of postulated water hammers and to identify appropriate corrective measures. This program will define the effects of postulated water hammers on the feedwater piping, piping supports, and other feedwater components. An outline of the program is provided as Enclosure III.

If you have any questions regarding this matter, please let me know.

Very truly yours,



K. P. Baskin

Enclosures(2)

ENCLOSURE I.

REQUEST FOR ADDITIONAL INFORMATION
ON STEAM GENERATOR WATER HAMMER
SAN ONOFRE, UNIT 1

Item 1

Provide information that demonstrates that the feedwater system and steam generator water level at your facility have been subjected to those transient conditions that are conducive to water hammer, i.e., the addition of cold feedwater or auxiliary feedwater to steam-filled feedwater piping and feeding. See NUREG 0291 Page 4 that was forwarded to you on September 2, 1977. Include the following:

- 1.1 Describe the expected behavior of steam generator water level as a result of reactor trip from power levels greater than 30% of full power. Include actual plant measurements of steam generator level and other available related data such as feedwater flow and auxiliary feedwater flow.
- 1.2 Provide the number and causes of loss of feedwater events during the operational history of the plant. You may refer to material submitted previously.
- 1.3 Provide the number and causes of loss of off-site power events during the operational history of the plant.

Response

- 1.1 The behavior of steam generator water level as a result of reactor trip from power levels greater than 30% was described in our letter dated December 27, 1977. This description is repeated and expanded upon below.

Steam generator level drops rapidly after a unit trip, almost always uncovering the feeding. The main feedwater pumps continue to run (except in the event of loss of offsite power) and the main feedwater regulators are positioned automatically according to average reactor coolant temperature (T avg.). If T avg. is above 545°F, the valves will continue to be controlled to maintain the normal 30% narrow range steam generator level set point. When T avg. falls below 545°F, the valves are automatically positioned to control feed flow at 5% of full load feed flow unless the high level override is actuated (at 90% steam generator level).

Normally, T avg. drops rapidly after a trip to 520-530°F and feedwater flow is controlled at 5%. The control scheme results in a momentary level drop to approximately 0% steam generator level followed by a rapid recovery to above 30%. At this point, the valves are placed on manual control and level is maintained near 50%. Since the top of the feeding is at 26%, water level drops well below the feeding under these conditions.

Although the feeding is typically uncovered following a reactor trip, operating experience has indicated that water hammer does not occur under these circumstances. This may be due to continued feedwater flow keeping the feeding full during the low level transient. Also, since the reflood is accomplished with relatively hot feedwater, the potential for rapid steam bubble collapse in the event of partial feeding drainage is reduced due to the low temperature difference between the steam and incoming feedwater.

- 1.2 This information was provided in our letter to the NRC of August 31, 1979. There have been two loss of feedwater incidents at San Onofre Unit 1, both of which were the result of safety injection actuation and the subsequent switchover of the feedwater pumps to safety injection service.
- 1.3 There has never been a loss of offsite power during power operation at San Onofre Unit 1. During a refueling outage, a loss of offsite power was experienced on June 7, 1973. This event was reported to the NRC in a letter dated July 6, 1973.

Item 2

If administrative controls have been adopted to limit the flow of auxiliary feedwater for the purpose of reducing the probability of water hammer, show when they were adopted and give the answers to items 1.1, 1.2 and 1.3 for before and after such controls were established.

Response

- 2.1 Changes to operating procedures were made in 1975 when the mechanism for potential steam generator water hammer was identified and brought to SCE's attention by Westinghouse. At that time, operating procedures were modified to caution operators to maintain level above the feeding at all times and to add feedwater slowly in the event the feeding did become uncovered. Of course, as pointed out in 1.1 above, in the event a unit trip occurs the feeding will more than likely be uncovered regardless of operator action to maintain steam generator water level above the feeding. This is indicated in the attached Table 1, which was included in our August 31, 1979 letter and has been updated to include the remainder of 1979.

Additional procedural changes were reported to the NRC in our December 27, 1977 letter and were implemented prior to January 31, 1978. These changes included maintaining the steam generator level at a nominal 50% rather than 30% when load is below 20% and the feedwater controls are on manual. This change from 30% to 50% reduces the frequency of feeding uncovering events which occur as a result of normal level fluctuation, during periods of low feedwater flow. These procedural instructions apply to both the main and auxiliary feedwater systems. The attached Table demonstrates the frequency of uncovering events before and after the procedural changes. Prior to 1978, feeding uncovering events frequently occurred during plant startup and shutdown. After January 1978, the table indicates these events have been reduced. With regards to a unit trip, following the rapid recovery of the steam generator level to 30%, the valves are placed on manual and level is maintained at 50%. This is pointed out in 1.1 above.

These procedural controls will be updated upon completion of planned modifications to the feedwater system to further reduce the probability of steam generator water hammer. In response to NRC requirements which have been established as a result of the Three Mile Island incident, automation of the auxiliary feedwater system and direct feedwater flow indication will be provided at San Onofre Unit 1. Automation of the auxiliary feedwater system is addressed in the response to Item 4. The direct feedwater flow indication will provide the operator in the control room with indication of the flow in each feedwater line to the steam generators. Once these design changes are implemented, in addition to maintaining steam generator level at 50%, the existing procedures will be modified to direct the station operator to limit the flow to 150 gpm (as opposed to adding feedwater slowly) to each steam generator following transients which result in the uncovering of the feeding. This flow limitation is based on tests conducted at Indian Point Unit 2, as reported in Westinghouse Technical Bulletin NSD-TB-75-7 dated June 10, 1975, and the feedwater piping configuration at San Onofre Unit 1. A flow of 150 gpm to each steam generator allows for a total feedwater flow of 450 gpm.

2.2 The two loss of feedwater incidents referred to in Item 1.2 occurred prior to the procedural modifications.

2.3 See the response to Item 1.3.

Item 3

If administrative controls have been adopted to limit the flow of auxiliary feedwater for the purpose of reducing the probability of water hammer, show that an adequate water inventory and flow will be maintained to accommodate all postulated transient and accident conditions.

Reponse

The existing and future administrative controls at San Onofre Unit 1 are described in Item 2.1. The design objectives and capabilities of the auxiliary feedwater system are described in Volume III, Section 3.1.6 of the San Onofre Unit 1 FSAR. As stated in the FSAR, the auxiliary feedwater system design objectives are as follows:

1. In the unlikely event of an extended loss of offsite power, each auxiliary feedwater pump flow capacity is sufficient to remove residual heat from the "infinite life" core at a rate equivalent to the rate of residual heat generation shortly after reactor trip. A flow of 300 gpm is sufficient to remove residual heat from a period approximately three minutes after trip.
2. The design head of each pump is sufficient to provide the design flow into the steam generators when the safety valves are blowing.

The storage capacity of cooling sources available to the auxiliary feedwater system, has been shown to provide sufficient decay heat removal for long-term cooling and to establish cold shutdown conditions.

The present administrative controls provide for admitting auxiliary feedwater flow to the steam generators slowly. As indicated in 2.1, with the addition of the feedwater flow indicators, these procedures will be revised to allow a flow of 150 gpm to each steam generator. This would allow a total auxiliary feedwater flow of 450 gpm. Based on this total flow rate, the design objectives of the auxiliary feedwater system, as outlined above, are not impacted by these procedural changes. In addition, the auxiliary feedwater system will be reevaluated with respect to its capability to handle all transient and accidents as part of the analyses being performed to meet TMI requirements.

Item 4

If auxiliary feedwater flow in your facility is not at present initiated automatically for normal and accident events, present your evaluation of whether automating the actuation of auxiliary feedwater might increase the probability of inducing steam generator water hammer. One of the signals that would automatically initiate the flow of auxiliary feedwater would be the steam generator low water level. This set point should be above the top of the main feedwater sparger to reduce the probability of steam generator water hammer.

Response

The automation of the auxiliary feedwater system is presently under review. As part of this review the steam generator water hammer phenomena will be addressed and appropriate features will be provided in the design to assure that the probability of inducing steam generator water hammer is not increased.

Item 5

Describe the means that will be used to monitor for the occurrence of steam generator water hammer and possible damage from such an event. Include all instrumentation that will be employed. Describe the inspections that will be performed and give the frequency of such inspections.

Response

The control room at San Onofre Unit 1 is situated such that an operator located in the control room can audibly detect water hammers in the feedwater piping system. This capability was demonstrated during the water hammer events described in Enclosure II. In the event a water hammer is detected in the feedwater piping system, the feedwater piping supports and components will be visually inspected for damage.

In addition, as required by the San Onofre Unit 1 Technical Specification 4.14, the feedwater piping system snubbers are inspected on a regular basis. The inspection interval varies with the number of inoperable snubbers found during the previous inspection. The maximum interval is 18 months.

Item 6

Describe the reporting procedures that will be used to document and report water hammer and damage to piping and piping support systems. Such reports were requested in our letter to you dated September 2, 1977.

Response

Severe steam generator water hammers which result in damage to piping or piping supports will be reported to the NRC in accordance with the provisions of our Appendix A Technical Specifications, Section 6.9.2.

TABLE 1. SUMMARY OF STEAM GENERATOR FEEDRING UNCOVERING INCIDENTS

| YEAR | NO. OF OUTAGES | | NO. OF OUTAGES W/NO UNCOVERING | NUMBER OF UNCOVERING INCIDENTS | | | | | | | | |
|--------|----------------|--------------------------|-----------------------------------|--------------------------------|----|----|-------|----|----|----------|----|----|
| | Total | (No. caused by trips) | | SHUTDOWNS | | | TRIPS | | | STARTUPS | | |
| | | | | A | B | C | A | B | C | A | B | C |
| 1967 | 5 | (3) | 2 | 1 | 3 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1968 | 8 | (2) | 2 | 3 | 2 | 1 | 2 | 1 | 2 | 3 | 3 | 1 |
| 1969 | 9 | (1)* | 1 | 8 | 3 | 5 | 1 | 1 | 1 | 4 | 10 | 8 |
| 1970 | 3 | (0) | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 3 | 1 |
| 1971 | 15 | (9) | 2 | 1 | 2 | 0 | 9 | 9 | 9 | 1 | 8 | 7 |
| 1972 | 13 | (4) | 1 | 1 | 6 | 3 | 4 | 4 | 4 | 5 | 20 | 9 |
| 1973 | 4 | (0) | 0 | 3 | 3 | 3 | 0 | 0 | 0 | 2 | 4 | 1 |
| 1974 | 8 | (2) | 3 | 0 | 1 | 0 | 3 | 3 | 3 | 3 | 2 | 5 |
| 1975 | 3 | (2) | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 6 | 3 |
| 1976 | 15 | (6) | 1 | 6 | 5 | 5 | 6 | 6 | 6 | 13 | 16 | 20 |
| 1977 | 7 | (4) | 0 | 0 | 1 | 0 | 4 | 4 | 4 | 12 | 6 | 18 |
| 1978 | 6 | (4) | 0 | 1 | 2 | 1 | 5 | 5 | 4 | 2 | 3 | 2 |
| 1979 | 7 | (2) | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 2 |
| TOTALS | 103 | 39 | 14 | 26 | 32 | 19 | 38 | 38 | 37 | 50 | 83 | 77 |

* Actually 2 trips occurred, however the charts were available for only one.

ENCLOSURE II

DESCRIPTION OF FEEDWATER LINE
WATER HAMMER EVENTS AT
SAN ONOFRE UNIT 1

Event No. 1

Date: April 29, 1972

Plant Status: Startup from hot shutdown conditions; turbine plant warmup in progress.

Feedwater Source: Condensate storage tank via an auxiliary feedwater pump.

Feedwater Temperature: 70°F (estimated)

Feedwater Flow Control: Auxiliary feedwater regulating valve.

Event Description:

| <u>TIME</u> | <u>DESCRIPTION</u> |
|----------------|--|
| 2200 | Steam generator level at approximately 50% and decreasing slowly during turbine plant warmup. Feedwater flow is less than recordable. |
| 2230 (approx.) | Plant operators note a water hammer on "C" feedwater line. Steam generator water level at approximately 20%. |
| 2246 | Feedwater addition large enough to be recorded, steam generator water level is raised above the feeding. Total time that the feeding is uncovered is approximately 15 minutes. No other water hammers noted during balance of plant startup. |

It is noted that this feedline waterhammer event is speculated as having caused the failure of the feedwater regulating valve for steam generator "C". This failed valve was an integral part of the April 30, 1972 safety injection actuation incident which was reported in our May 30, 1972 letter.

Event No. 2

On January 14, 1974, during a unit outage, a routine inspection inside containment revealed damage to two main steam line knee brace supports, a "B" feedwater line knee brace support, and a "B" feedwater line hydraulic snubber. A description of the damage, conclusions and corrective actions is provided in our July 14, 1975 letter. Although it was initially speculated that the supports may have been damaged by water hammer, it was subsequently determined that the supports were improperly designed and installed.

Event No. 3

Date: May 14, 1979
Plant Status: Unit trip from full power.
Feedwater Source: Condenser hotwells via main feedwater pumps.
Feedwater Temperature: 100°F (estimated)
Feedwater Flow Control: Main feedwater regulating valves (initially).

Event Description:

| <u>TIME</u> | <u>DESCRIPTION</u> |
|------------------------|--|
| 1043 | Unit tripped, steam generator levels dropped rapidly to 0% as normal, but did not recover due to incorrect position setpoint for main feedwater regulating valves (no feedwater flow). Steam generator levels drop low off narrow range indication. |
| 1045-1056 (approx.) | Operators begin to restore steam generator level using auxiliary feedwater regulating valves. An operator in the general vicinity of the feedwater regulating valves heard several water hammers and noted a water hammer of the "B" feedwater piping. The air supply line to the "E" auxiliary feedwater regulating valve was broken presumably as a result and the valve shut. |
| 1100 | No further water hammers were noted and water level in "B" steam generator was gradually restored to normal using the main feedwater regulating valve. Water levels in "A" and "C" steam generators gradually restored to normal using auxiliary feedwater regulating valves. |
| 1125 | Air supply line to "E" auxiliary feedwater regulating valve repaired. "A" steam generator level above feeding. |
| 1150 | "C" steam generator level above feeding. |
| 1215 | "B" steam generator level above feeding (26%). |

This event was reported to the NRC Regional offices in our letter dated June 19, 1979.

ENCLOSURE III

FEEDLINE WATERHAMMER
EVALUATION PROGRAM
SAN ONOFRE UNIT 1

- 1) Develop water hammer forcing functions for:
 - a) "Classic" type water hammers
 - b) Valve operation (both check valve slam and feedwater regulating valve operation) hydraulic effects.
- 2) Apply these hydraulic effects to as-built feedwater piping configurations.
- 3) Evaluate stress levels in piping and piping supports.
- 4) Evaluate suitability of piping components such as valve operators, flow instrumentation, etc., to withstand mechanical shocks.
- 5) Determine effects of an automated auxiliary feedwater system.
- 6) Evaluate Creare recommendations in accordance with operating experience
 - J tubes
 - Topside vents
 - Pre-heating of auxiliary feedwater
 - Auxiliary feedwater system nozzle
 - Flow limits
- 7) If necessary develop a test program to evaluate auto auxiliary feedwater
- 8) Implement corrective measures.