U.S. NUCLEAR REGULATORY COMMISSION
REGION V

Report No. 50-206/86-07

Docket No. 50-206

License No. DPR-13

Licensee: Southern California Edison Company
P. O. Box 800, 2244 Walnut Grove Avenue
Rosemead, California 92770

Facility Name: San Onofre Unit 1

Inspection at: San Onofre, San Clemente, California

Inspection conducted: February 12 through April 25, 1986

Inspectors: for F. R. Huey, Senior Resident Inspector, Units 1, 2 and 3 — 5/15/86 Date Signed

for J. P. Stewart, Resident Inspector — 5/15/86 Date Signed

for A. D'Angelo, Resident Inspector — 5/15/86 Date Signed

for J. E. Tatum, Resident Inspector — 5/15/86 Date Signed

for R. C. Tang, Resident Inspector — 5/15/86 Date Signed

Approved By: P. H. Johnson, Chief, Reactor Projects Section 3 — 5/15/86 Date Signed

Inspection Summary

Inspection on February 12 through April 25, 1986 (Report No. 50-206/85-07)

Areas Inspected: This is the report of a special inspection to review the circumstances involving a feedwater system water hammer which occurred on Unit 1 on November 21, 1985. The purpose of this special inspection was to address those aspects of the Unit 1 water hammer event which appear to involve a violation of NRC requirements. The results of other inspection activities related to the water hammer event and subsequent plant restart will be included in routine monthly inspection reports. Inspection procedure 93702 was followed during this inspection.

Results: Three apparent violations were identified involving:

1. Failure to implement an inservice testing program that was adequate to detect failures in safety related equipment. These undetected equipment failures resulted in the loss of capability to provide automatic auxiliary feedwater to steam generators as required by Technical Specifications and resulted in extensive water hammer damage to the feedwater system (paragraph 3).

2. Failure to implement effective actions to correct malfunction of safety related equipment following identification of equipment deficiencies several months prior to the event (paragraph 4).

3. Failure to provide appropriate procedures for the troubleshooting and prompt isolation of faults on 4KV electrical equipment (paragraph 5).

DETAILS

1. Persons Contacted

Southern California Edison Company

*H. Ray, Vice President, Site Manager
*G. Morgan, Station Manager
*M. Wharton, Deputy Station Manager
D. Schone, Quality Assurance Manager
R. Krieger, Operations Manager
D. Shull, Maintenance Manager
*J. Reilly, Technical Manager
*B. Zintl, Compliance Manager
J. Reeder, Operations Superintendent, Unit 1
J. Schramm, Plant Coordinator, Unit 1

*Denotes those attending the exit meeting on April 21, 1986.

2. Background

On November 21, 1985, subsequent to a reactor trip in Unit 1, a water hammer occurred in the feedwater piping to the "B" steam generator, causing a feedwater leak (bonnet leak on "B" feedwater bypass check valve) and significant damage to the feedwater piping and supports. The conditions for water hammer were initiated by an electrical fault on the power supply to the 1C 4KV electrical bus in conjunction with the simultaneous failure of five safety related check valves associated with the feedwater system. The five failed check valves included the three check valves in the three feedwater lines (FWS-345, 346, 398) and the two check valves on the discharge of each main feedwater pump (FWS-438, 439). These failures permitted the main feedwater lines to drain back through the condensate system and overpressurize and rupture the shell of the east fourth and fifth point feedwater heater.

Subsequent to the event an NRC Incident Investigation Team (IIT) was sent to the site to determine what happened, identify the probable causes and make appropriate findings and conclusions to form the basis for possible follow up actions. The IIT findings and conclusions are documented in NUREG-1190.

The adequacy of licensee's emergency response during this event was reviewed by the NRC Region V Emergency Preparedness Section and is documented in inspection report number 50-206/86-16.

An NRC Vendor Programs Branch inspection team (VPB) conducted an inspection on site to: (1) assess the root cause of the valve failures and corrective actions; (2) evaluate the adequacy of the new check valve design; (3) determine the ability of the IST program to detect degraded or failed valves and (4) assure other systems are not subject to similar failure. Their findings and conclusions are to be documented in inspection report number 50-206/86-15.

This special inspection consisted of an examination of the above reports and additional observations and discussion with licensee representatives to evaluate licensee compliance with regulatory requirements.

3. Valve Inservice Test Program

a. History of Check Valve Problems:

(1) In the mid and late 1970's, there were several instances in which main feedwater (MFW) check valves were determined to have failed or to require maintenance of valve internals. Specifically:

- 12/73 - Internal noise was noted at the "B" 10" check valve (FWS-346). The valve was repaired.
- 7/74 - The "C" 10" check valve (FWS-398) was found to have failed. The disk had separated from its hinge. The valve was repaired.
- 1975 Refueling - All three 10" check valves (FWS-345, 346, and 398) found to have extensive wear on hinge pins and arms. The valves were repaired.
- 4/76 - The "B" 10" check valve (FWS-346) was found to have failed. The disk had separated from its hinge. The valve was repaired.
- 1977 Refueling - The 10" check valve disks (FWS-345, 346, and 398) were modified to include an antirotation device to prevent the disk from turning.
- 4/79 - The east main feedwater (MFW) pump discharge check valve (FWS-438) failed to properly close, allowing reverse pump rotation. The valve was repaired (internals replaced due to "excessive play").

(2) The licensee believed that all of the check valve problems noted above were the result of a lack of antirotation devices. After their modification in 1977, the three 10" feedwater regulator check valves were inspected in 1978 and 1980 with no problems identified. Cotter pins, washers, and nuts were replaced during the 1980 inspection. The two 12" MFW pump discharge check valves were repaired (new internals installed) in 1979 as noted above. These valves were inspected in 1980 and 1981 and found to be in good condition.

b. Maintenance History not Factored into Test Program:

(1) The maintenance history of the feedwater system check valves was not factored into the valve test program. As a result, this data base was not available to test engineers responsible for establishing valve testing priorities. The 10" check valves were not considered safety related and so designated on

licensee drawings until 1980. These valves were not added to the Q-List until 1985, and records of their maintenance history prior to that time were incomplete.

(2) After the steam generator sleeving outage in 1981, the unit operated at reduced temperature and reactor power (approx. 92%), which resulted in reduced feedwater flow. The licensee has concluded that the five feedwater check valves were not fully open with this reduced flow, and were damaged by flow-induced vibration during extended operation at this reduced feedwater flow rate.

c. Scope of Licensee Implementation of Valve Testing

(1) 10 CFR 50, Appendix B, Criterion XI requires that licensees implement a test program that is adequate to assure that plant systems and components perform satisfactorily in service.

(2) The Southern California Edison Company (SCE) Topical Quality Assurance Manual sets forth the policies and general requirements for establishing and implementing the quality assurance program by SCE in accordance with Nuclear Regulatory Commission Regulations. Chapter 7-E of the SCE Topical Quality Assurance Manual sets forth the quality program for controlling inservice inspection and testing by requiring conformance with Section XI of the ASME code. The licensee relied on the performance of the ASME Section XI program to satisfy the test control requirements of 10 CFR 50, Appendix B.

(3) SCE procedures SO1-V-2.15, "In-Service Testing of Valves Program" and SO1-12.4-2, "Operations In-Service Valve Testing" implement the specific in-service testing (IST) requirements for Unit 1 valves. The procedures provided for the feedwater check valves to be tested quarterly; however, the program allowed the valves not to be tested if the plant was not in the proper mode for performance of the test. As noted above, the program did not make provisions for consideration of maintenance history or operational problems in determining valve testing priorities. All five of the feedwater check valves which failed were tested satisfactorily during October - November 1984 as part of the return-to-service program. However, owing to the mode-dependent deferrals allowed by the IST program, the 12" valves were not tested following return to service, and the 10" check valves were tested only once (in February 1985). During this test, performed on February 24, 1985, two of the 10" check valves (FWS-345 and 346) initially failed when tested in Mode 5 (cold shutdown) conditions. A maintenance order for their inspection was prepared. The valves tested satisfactorily (on February 26, 1985) following plant heatup, and the maintenance order was cancelled.

(4) As noted above, the feedwater check valves had experienced numerous failures, which the licensee believed had been corrected by modifications in 1977. Although the valves were

inspected in 1978 and 1980, no additional inspections were performed as a part of return to service efforts in 1984.

(5) The auxiliary feedwater system is a safety related system which has associated with it a number of technical specification requirements. Section 3.4.1, which is applicable in modes 1, 2, and 3, requires that system piping and valves directly associated with the above components (auxiliary feedwater pumps and tank) be operable. Section 3.4.3, which is also applicable in modes 1, 2, and 3, requires that both steam generator auxiliary feedwater pumps and associate flow paths shall be operable with provisions for one auxiliary feedwater pump being inoperable for up to 72 hours before mode de-escalation.

In addition to piping system and mechanical component requirements, Section 3.5.7 also requires that the auxiliary feedwater system have an automatic initiation signal to start the auxiliary feedwater pumps. Prior to the water hammer event of November 21, 1985, the licensee had the correct system alignment of the auxiliary feedwater system and the system was considered by the licensee to be available for automatic start and injection to the steam generator. However, the three feedwater regulating check valves (FWS-345, 346, 398) had failed open and were not able to close and prevent reverse flow in the main feedwater line to each steam generator. These three check valve failures along with a failure of the main feedwater pump check valves (FWS-438, 439) and concurrent loss of both main feedwater pumps prevented the auxiliary feedwater from reaching the steam generators until plant operators manually closed three block valves (MOV-20, 21, 22) per the reactor trip procedure SO1-1.0-11.

The failure of the five feedwater check valves prevented auxiliary feedwater from reaching the steam generators without manual operator action. Inadequacy in the IST program and the resulting inoperability of the auxiliary feedwater system was identified to the licensee as an apparent violation (86-07-01).

4. Corrective Actions Following Indications of Check Valve Malfunction

a. During normal power operation a loud rapping or metal tapping noise was heard by licensee personnel on June 24, 1985, apparently near the manual block valve downstream of the 10" check valve. An internal licensee document reported the following actions as having been taken:

"The block valve was radiographed, exercised to a partially closed position and the vendor was contacted for information concerning the possible causes.

"Vibration and stethoscope measurements were taken at the block valves, the check valve and elsewhere along the line. These measurements indicated that the noise was located at the manual

block valve downstream from the check valve and that it was almost unnoticed at the check valve."

b. The anomaly in the "B" feedwater line was brought to the attention of the onsite review committee, which met on July 18, 1985. The committee reviewed the results of the noise investigation which had been conducted to identify the source of the noise and determine potential consequences of continued operation. Conclusions reached as a result of the investigation were that continued operation of the unit would not decrease the margins of safety to the plant. Reportedly, the primary concern of the licensee was that valve internal parts would be small enough to enter the steam generators and potentially damage the steam generator tubes. The licensee's investigation did not address the potential for or safety consequences of check valve failure from the standpoint of drain down of the feed lines or diversion of auxiliary feedwater from the steam generators. All of the feedwater check valves were of the same design, subject to similar conditions and had a prior history of failures.

c. The licensee's noise investigation identified that the feed check valve or manual block valve could have failed, and a visual inspection to confirm valve condition was scheduled for a subsequent outage. When the valve noises subsequently disappeared (apparently due to the valve disk falling to the bottom of the valve body) no additional attention was paid to the valve and the licensee did not inspect or test the valves during subsequent plant outages in August and September 1985.

d. 10 CFR 50, Appendix B, Criterion XVI requires that licensees implement a program that is adequate to assure that conditions adverse to quality, such as equipment failures, malfunctions and deficiencies are promptly identified and corrected. As noted above, the licensee did not fulfill this requirement with regard to the check valve deficiencies noted prior to the water hammer event. This was identified as an apparent violation (86-07-02).

5. Procedures for Troubleshooting 4KV Electrical Faults

a. Operating Instruction number SO1-9-7, Revision 2, "4160V and 480V Bus and Feeder Faults" provided the instructions for dealing with 4160 volt system grounds and faults. The procedure listed applicable licensing commitments, prerequisites, precautions, checklists and instructions for troubleshooting the electrical system. Section 6.2 of the procedure provided the instructions to be followed and stated that: "If a 4160V ground alarm is received or if a 4160V bus residual ground indication is significantly greater than normal, then locate the ground by one of the following methods:." The procedure then listed a number of options available for trouble shooting the 4160 volt bus. The order in which troubleshooting steps may be performed was at the discretion of the personnel involved. These options included the following:

6.2.2 Transfer or Stop redundant auxiliary equipment and observe the ground meter.

6.2.3 DE-ENERGIZE as possible one-of-a-kind auxiliary equipment and observe the ground meter.

6.2.5 REDUCE Unit load as necessary and DE-ENERGIZE major equipment such as circulating water pumps, feedwater pumps etc. one at a time and observe the ground meter.

6.2.6 When the grounded circuit is identified, then initiate a Maintenance Order to have the circuit inspected and tested.

b. The procedure did not provide criteria for the length of time operation may continue with bus 1C or 2C in parallel with bus 1A or 1B.

c. Operating Instructions SO1-9-7 and SO1-9-2, "4160V Systems Operations", provided precautions on operation of diesel generators in parallel with the C auxiliary transformer, based on potential short circuit currents in excess of the 4160V switchgear rating. These procedures did not provide similar guidance on operation of auxiliary A or B transformers in parallel with the auxiliary C transformer. With these transformers in parallel operation, the transformers are able to deliver a total of 263 MVA to a fault on the load side of the bus; however, the bus and circuit breaker ratings are only 250 MVA.

d. The licensee considered that paralleling of buses was properly performed within the scope of procedure step 6.2.2 of SO1-9-7, following the paralleling directions of SO1-9-2. As a result, the 1C bus (and c auxiliary transformer) was tied to the 1A bus (and A auxiliary transformer) for a total time period of more than six minutes.

e. The A auxiliary transformer is Y-wound with its neutral connected to ground through a high resistance. During the period that the faulted C auxiliary transformer was paralleled to the A auxiliary transformer, this high resistance path to ground increased the leakage current through a known fault in a feeder cable from the C transformer. This resulted in accelerated insulation breakdown and subsequent major short circuiting between phases, causing a loss of the C transformer due to the action of protective relays.

f. 10 CFR 50, Appendix B, Criterion V requires that activities affecting quality be prescribed by procedures of a type appropriate to the circumstances. As noted above, the procedures implemented by the licensee for trouble shooting faults associated with the 4KV safety related electrical buses were not appropriate, in that they did not provide adequate guidance to plant operators to preclude improper actions that resulted in a loss of all off site power to the Unit, which initiated the water hammer event on November 21, 1985. This was identified as an apparent violation (86-07-03).

6. Safety Significance of Event

The Unit 1 water hammer event challenged the integrity of the plant's secondary heat sink; five safety related valves in a single plant system were permitted to fail and remain undetected until the plant was subjected to a significant transient. This transient was initiated by operator actions associated with troubleshooting of an electrical fault on the plant's 4KV system. The specific aspects of the event which were significant to safety included:

a. Failure of the five feedwater check valves prevented automatic injection of auxiliary feedwater to the steam generators and, without proper operator action, would have removed all 3 steam generators as a heat sink.

b. The time interval required for operator action to manually isolate the feedwater headers set up the conditions for a severe water hammer which resulted in extensive damage to one of the feedwater lines.

c. The water hammer caused an unisolable leak on the secondary side of the B steam generator, resulting in a reactor coolant system cooldown transient and loss of the B steam generator as an effective heat sink.

d. The problems associated with troubleshooting of the 4KV ground on the 1C electrical bus resulted in a temporary loss of all off site power to the station during Mode 1 operation.

7. Conclusions

a. The in-service testing program implemented by the licensee did not meet the requirements of 10 CFR 50, Appendix B, Criterion XI, in that it did not detect safety related component failures in the feedwater system. These failures resulted in failure of the auxiliary feedwater system to perform satisfactorily when required. In particular, the licensee's program did not properly consider prior equipment history associated with components covered in the program.

b. The licensee failed to take effective corrective actions following indications of a possible safety related check valve malfunction, as required by 10 CFR 50, Appendix B Criterion XVI. Furthermore, the licensee did not inspect or test the valve during subsequent plant outages.

c. The licensee did not provide appropriate procedures for troubleshooting and isolation of faults associated with station electrical equipment, as required by 10 CFR 50, Appendix B, Criterion V. In particular, inappropriate operator actions associated with troubleshooting of an apparent ground on a safety related 4 KV bus resulted in delayed isolation and deenergization of the C auxiliary transformer. This delay allowed the existing fault

conditions to rapidly deteriorate, causing a loss of all off site power and initiating the water hammer event.

8. Exit Meeting

On April 21, 1986, an exit meeting was conducted with the licensee representatives identified in Paragraph 1. The inspectors summarized the inspection scope and findings as described in this report.