U. S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-255/93023(DRS)

Docket No. 50-255 License No. DPR-20

Licensee: Consumers Power Company
1945 West Parnall Road
Jackson, MI 49201

Facility Name: Palisades Nuclear Power Plant

Inspection At: Covert, MI 49043

Inspection Conducted: September 20 through November 27, 1993

Inspectors: J. F. Smith for 12-23-93
Date

J. A. Gavula for 12-23-93
Date

Approved By: J. M. Jacobson, Chief 12-23-93
Materials and Processes Section
Date

Inspection Summary

Inspection on September 20 through November 27, 1993 (Report No. 50-255/93023(DRS))

Areas Inspected: Announced reactive inspection of activities related to a leak in the Inconel 600 safe end of the pressurizer PORV line.

Results: No violations were identified during this inspection. The licensee established a plausible root cause for the failure, effected a temporary repair of the failed member, and inspected areas with similar materials and operating conditions for similar defects. No other circumferential defects were disclosed, but two RTD nozzles were repaired as a result of the presence of axial cracking.

Radiography of the area shortly before the failure disclosed the presence of an indication. However, the accuracy of the ultrasonic technique used to characterize and size the indication was compromised by the joint geometry.

An apparent lack of management involvement was noted early in the repair effort, as evidenced by the slow response in providing a comprehensive inspection/repair plan. Also, the initial consideration of the generic aspects of this PWSCC failure was considered weak.

DETAILS

1. Persons Contacted

Consumers Power Company (CPCo)

D. Bemis, Systems Engineering
V. Beilfuss, Assistant Outage Manager
*J. Decker, NDT Services Supervisor
*J. Kuemin, Licensing Administration
*R. Margol,Systems Engineering Section Head
J. Nordby, NECO Welding Engineer
*K. Osborne, Systems Engineering Manager
*R. VanWagner, Systems Engineering

Nuclear Regulatory Commission (NRC)

L. Banic, EMCB
M. Hum, EMCB
J. Jacobson, Chief, M&PS, Region III
*M. Parker, Senior Resident Inspector

Idaho National Engineering Laboratories (INEL)

B. Brown, NRC Consultant, NDE

*Denotes those participating in the telephone exit meeting on November 29, 1993.

2. Background

On September 16, 1993, a leak occurred in the nozzle of the pressurizer power operated relief valve (PORV) line. The pressurizer is a low alloy steel vessel which is clad internally with stainless steel. The cladding extends inside the PORV nozzle to the weld joint with the Inconel 600 safe end. The safe end forms a physical transition from the 1 3/4" wall of the clad portion of the nozzle to the 0.438" wall of the stainless steel PORV pipe and is welded to the stainless steel pipe. The leak occurred in the weld heat affected zone (HAZ) on the Inconel side of this joint.

3. Sequence of Events

June 1993

A flaw in the pressurizer relief valve nozzle safe end was found by radiography and considered to be an indication from original construction, rather than a service-induced flaw. NRC inspectors onsite at the time reviewed these radiographs and informed the licensee that, in their opinion, the indication should be evaluated as a crack. The licensee elected to assume the more conservative position and evaluated the indication as a crack. The evaluation consisted of performing an ultrasonic inspection (UT) to determine size of the indication and performing an engineering analysis to determine the suitability of the nozzle for future service. The evaluation was based on the assumption that the indication was a service-induced crack and on the dimensions determined by UT (1 7/8" length and less than 30% through wall dimension, originating at the inside diameter). The results of that evaluation, summarized in internal memorandum BVV93*006, dated July 20, 1993, concluded that the flaw was not likely to grow and that the nozzle was suitable for further service. Additionally, Palisades planned to perform a re-examination of the weld during the next refueling outage. The inspectors found the licensee's response to be appropriate for the data available at the time.

<u>September 16</u>

Shortly after the plant reached hot shutdown (532 degrees F, 2060 psia), a 0.2 gallon per minute leak was identified on containment sump level instrumentation and a steam leak was identified in the pressurizer shed shortly thereafter.

<u>September 17</u>

Plant achieved cold shutdown permitting direct visual and nondestructive examination of the crack, including radiography (RT). The crack was characterized as circumferential, in the safe end, near the safe end to pipe weld, and approximately three inches in length. A section containing the crack was cut out of the line for evaluation. The section included approximately 3/4" of Inconel safe end and several inches of pipe.

4. <u>Root Cause Investigation</u>

a. <u>Metallurgical Examination</u>

The nozzle-to-pipe weld section containing the crack was cut on the longitudinal axis to form two segments of approximately 180 degrees, each, with the defect entirely contained in one section. The central portion of the crack was removed and mechanically fractured at the crack. The remaining pieces were sectioned to provide metallographic cross-sections of the weld for macro and micro examination.

The licensee's metallurgical analysis of the sections is included in internal memorandum ESM-110-93, MET Project No. 259339070140, dated September 27, 1993. It stated that the failure was believed to be the result of primary water stress corrosion cracking (PWSCC). Review of the samples also disclosed the following information:

- The weld root had been repaired internally for a portion of the inside diameter, adjacent to the crack initiation site.

- The crack initiation site was in the HAZ of the Inconel 600 side of the safe end to pipe weld and the crack propagated straight out to the outside diameter within the confines of the HAZ.

- The cracking was intergranular and was near through-wall prior to plant startup.

The inspectors reviewed the metallographic evaluation and found it to be acceptable. The fractured crack sample was noted to be almost free from evidence of fresh fracture surface, indicating that the fracture had existed for quite some time. Most of the surface was oxidized and covered with coarse grains.

b. Review of Previous Inspection Results

The failure of previous nondestructive examinations (NDE) to disclose the presence of a nearly through-wall crack at this joint was a concern. The licensee radiographed the joint after the leak occurred and engaged a consultant to review this and previous radiographs of the area. The consultant indicated that the construction radiographs were of poor quality and interpretation in the area of concern was not feasible. He also indicated that both the June and the September radiographs showed cracks. An NRC NDE consultant, on site with the NRR group at the time, reviewed the radiographs and came to essentially the same conclusion. The inspector reviewed the June and September radiographs and concurred that they showed cracks.

Based on the above observations, radiography is capable of identifying this form of failure. However, ultrasonic sizing of the defect obviously failed to properly characterize it. Review of the UT examination performed to size the defect was inconclusive in that the test was performed manually and there were no equipment-generated records of the results. However, it was learned that the geometry of the sample was unsuited to direct inspection without removal of the weld reinforcement. The irregular weld root geometry also contributed to the difficulty of interpretation.

The licensee indicated that further evaluation of NDE techniques will be conducted as a result of this problem, and that enhanced techniques will be applied in the augmented inspection program for safe ends, beginning in the next refueling outage.

The interpretation of radiographs is not an exact science. However, it is the staff's opinion that the licensee's interpretation of the June radiograph should have been more conservative because the Combustion Engineering Owners Group (CEOG) had identified pressurizer nozzles as a most likely place for PWSCC to occur.

c. <u>Effect of Previous Modification of PORV Line</u>

During the investigation into the pipe crack, it was observed that the first elbow in the PORV line had a wall thickness much greater than specified on the installation drawings. This original construction discrepancy potentially compromised the 1989 PORV piping modification because of the stiffer properties at this elbow. The modification rerouted piping from the second elbow in the PORV line and significantly increased the restraint configuration to accommodate revised hydrodynamic loads. There was a concern that the combined increase in stiffness had caused significant thermal stresses at the pressurizer PORV nozzle.

The licensee evaluated the effect of the thicker first elbow in Engineering Analysis EA-SP-03375-04. In addition, the calculation assessed the impact of several nonconservative assumptions used in the modification analysis regarding the horizontal thermal displacement of the PORV nozzle and temperature distribution in the PORV line during normal operation. NRC inspectors reviewed the initial revision of the analysis, walked down applicable portions of the PORV piping, and had no adverse comments. A minor discrepancy was noted during the review of the pressurizer thermal expansion calculation EA-SP-03375-03. However, the incorrect subtraction of the vessel thickness in the L_2 calculation only resulted in approximately a 1 percent displacement inaccuracy and was judged by the inspector not to be significant.

The results of the calculations indicated that the maximum PORV piping stress was approximately 91 percent of allowable at a location 9 feet from the pressurizer nozzle. The maximum stress level at the nozzle was calculated to be less than 50 percent of allowable. Based on these results, the NRC inspectors concluded that the 1989 PORV modification was acceptable and that even with the increased loads at the nozzle, the thermal expansion stresses did not significantly contribute to the cause of the pipe cracks.

5. <u>Repair of the PORV Line Weld</u>

The PORV line was repaired by re-use of the original safe end, which was modified to form a new weld preparation. The replacement piping was divided into two lengths. The first, which was welded to the safe end, was short enough to allow removal of the inside weld reinforcement to enhance the weld inspection. The addition of the second length of pipe closed the system. The completed weld was inspected by RT and by PT on both the inside and the outside surfaces.

6. Inspection of Other Pressurizer Nozzles

Based on the needs identified by the failure and in response to questions received from NRR, the licensee formulated the action plan transmitted to NRC by letter dated October 7, 1993. The plan describes the 136 pressurizer nozzles that contain Inconel 600. This includes 120 heater wells, 8 level instruments, 2 temperature instruments, 3 safety valve flanges, 1 spray line, 1 surge line and 1 PORV line. It also includes a description of the PORV line repair, an identification of the inspections completed or to be completed on similar nozzles and long term corrective actions. The licensee was involved in frequent discussions with NRR concerning the performance and results of these activities.

Visual examination was performed on the heater wells. The PT, RT, and UT performed during the period of September 24 through 29 were reviewed by the NRC NDE consultant. This generally covered the PORV line, three relief valves and the spray line. These nozzles were of primary interest due to the environment in the pressurizer at these locations. The NRC consultant confirmed that the examinations were adequate and that they disclosed no significant indications.

The staff noted an initial lack of management involvement in formulating a plan which coordinated the many tasks necessary to resolve the problem and restore the plant to operation. However, work was done in all the necessary technical areas of the job and the various operations progressed with minimal delays.

7. Instrument Nozzle Inspections

Among the additional penetrations inspected as a result of the PORV line leak were 2 pressurizer thermowell nozzles, 8 pressurizer level nozzles, 3 cold leg RTD nozzles, and 10 hot leg nozzles. The 3 cold leg nozzles penetrate the horizontal pipe at an angle of 45 degrees (hot leg nozzles enter horizontally). The weld joints which secure and seal these nozzles are located at the inside surface of the pipe or vessel. Through the remainder of the wall, there is no physical connection. These penetrations have been observed to fail at other plants. The normal failure mode is axial cracking adjacent to the weld.

The inspector observed the reported oxidation in the area below the three cold leg nozzles, and confirmed that there were no boron crystals in the area. The inspector agreed that this was not a significant indication of leakage because the piping which ran over the area was seen to be wet with condensation and dripping into this area. When the cold leg is relatively cool, any water reaching the nozzle area would be drawn into the crevice by capillary action and accumulate there until heating caused it to run out and down the path made by the corrosion.

The 10 hot leg RTDs showed no signs of oxidation or boron crystals. The eight level indicators were confirmed to be acceptable by radiography. Eddy current testing of the nozzle for the vapor phase pressurizer temperature instrument disclosed four axial indications approximately 0.4 inches in length extending from the end of the nozzle. Because of the limitations in accessibility, the liquid phase pressurizer temperature instrument near the bottom of the pressurizer could not be readily inspected by eddy current. However, the presence of a leak was established by boron crystals at the nozzle. Confirmation of the nature of the leak at the vapor phase instrument provided strong circumstantial evidence of a similar leak in the liquid phase instrument. The licensee elected to repair both nozzles. The repair consisted of the nozzles being seal welded at the outer surface of the pressurizer. Each nozzle was then cut circumferentially (from the inside) at approximately the mid-wall position of the nozzle by electrical discharge machining. The cut was made to reduce the potential for thermal stress build-up during transients, since both inner and outer ends of the nozzle were then secured by welding.

The staff considered the licensee's original plan to investigate other areas for similar cracking to be weak, because it did not include instrumentation nozzles. The CEOG had previously identified the tendency of instrumentation nozzles to fail by PWSCC.

8. Exit Meeting

The NRC inspectors held a telephone exit meeting with licensee representatives (denoted in Section 1) at the conclusion of the inspection on November 29, 1993. The inspectors summarized the purpose, scope and findings of the inspection. The inspectors also discussed the likely informational content of the inspection report with regards to documents or processes reviewed by the inspectors during the inspection. The licensee did not identify any such documents or processes as proprietary.