U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-255/84-23(DRS)

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

Licensee: Consumers Power Company
212 West Michigan Avenue
Jackson, MI 49201

Facility Name: Palisades Nuclear Generating Plant

Inspection At: Covert, MI

Inspection Conducted: October 1 through December 5, 1984

Inspectors: J. M. Jacobson J J Hanson for 12/21/84 Date

P. R. Wohld P. R. Wohld Dec. 21, 1984 Date

Approved By: D. H. Danielson, Chief J J Hanson for 12/21/84 Date
Materials and Processes Section


Inspection Summary

Inspection on October 1 through December 5, 1984 (Report No. 50-255/84-23(DRS))
Areas Inspected: Special safety inspection by Region III-based inspectors of quality records, procedures, hardware, and test data related to failure of the bolted impeller to shaft joint of a Primary Coolant System pump. The inspection involved a total of 48 inspector-hours onsite by two NRC inspectors including 0 inspector-hours onsite during off-shifts, and 42 inspector-hours by two NRC inspectors at the Region III office.
Results: No items of noncompliance or deviations were identified.

## DETAILS

1. Persons Contacted

Consumers Power Company

R. Montross, Plant Manager
*J. Hinkle, Engineer
*D. VandeWalle, Licensing Administrator
#J. D. Alderink, Mechanical Superintendent
#M. E. Foreman, Engineer
#B. A. Low, Primary Systems Section Head
#R. T. Carrier, Engineer
#D. VanDenBerg, Reactor Engineer

Battelle-Columbus Laboratories

*Dr. C. Jaske, Senior Research Scientist
*W. Stiegelmeyer, Research Scientist

*Denotes those attending the exit interview held on November 9, 1984.

#Denotes those attending the exit interview held on December 5, 1984.

Additional plant technical and administrative personnel were contacted by the inspector during the course of the inspection.

2. Primary Coolant System Pump Mechanical Failure

On September 16, 1984, Palisades Nuclear Power Plant experienced the mechanical failure of three out of four Primary Coolant System (PCS) pump shaft seals on PCS pump P-50C. This initiated associated alarms and caused isolation of the seal leakoff excess flow check valve for this pump. A rapid, controlled plant shutdown was initiated on failure of the third seal as required by plant operating procedures.

Recurrent vibration alarms had been present in days prior to the event; however, neither special monitoring done in response to the alarms nor the actual vibration levels present resulted in a determination of unacceptable pump conditions. Nevertheless, on pump disassembly for repair of the seals, major damage to the pump impeller, shaft, and other parts was discovered. A detailed analysis and evaluation by the licensee indicates that the event was most probably initiated by an inadequate mechanical preload on the cap screws which attach the pump impeller to the pump shaft end plate. The capscrews failed in fatigue which allowed the impeller to fall to an unbalanced condition and wear against the pump bowl wear ring. The pump seals were apparently damaged by the subsequent abnormal shaft movement, leading to discovery of the initial failure and more extensive mechanical damage. A detailed discussion of the licensee's activity and Region III inspection related to this event follows.

During unbolting of the pump motor coupling to repair the P-50C seal failure, the vertical pump shaft failed to drop 3/16 inch as normally expected, signaling the existence of a mechanical abnormality within the pump which required pump disassembly and inspection. On pulling the shaft, the impeller remained in the pump bowl, indicating that the pump had experienced a major mechanical failure. All eight 1.25 inch cap screws holding the impeller to the pump shaft end plate had failed and two of the four 1.5 inch drive pins were sheared. Rubbing damage was found in several areas both on rotating and stationary pump parts.

On learning of the more significant pump damage, Region III increased its effort in reviewing the event and following the licensee's recovery effort. The impeller, shaft, pump bowl, and other parts were inspected onsite by two NRC inspectors to assess the nature and extent of the pump damage prior to removal or repair by the licensee. The licensee's investigation of the failure, repair of the pump, and final recovery to plant operation were closely followed and reviewed to assure that the nuclear safety aspects of the event were properly addressed, including potential generic implications.

It was readily evident on review of the plant strip chart recordings of reactor temperature and pressure that no reactor coolant flow abnormalities were seen by the reactor which was at 57 percent power at the time of the seal failure. The impeller continued to rotate at motor shaft speed until manually stopped by the reactor operator during plant shutdown according to procedures. Torque was maintained to the impeller during the event by the two remaining drive pins that, while deformed, were still intact. The inspector determined that had the impeller stopped rotating with the shaft, a low flow reactor trip would have been available to provide plant protection. Safety analyses reported in the Palisades FSAR for a locked rotor indicate that any adverse effects from such an event would have been minimal.

The licensee's investigation indicates that the pump impeller which failed had been installed in the plant as original equipment but was subsequently removed for modification during 1970-1971 and then held in storage as a spare. The impeller was recently (December 1983) taken from storage and reinstalled to replace an impeller that had lost a piece on one of its blades. The impeller and shaft were replaced as a complete assembly as received from the vendor after the 1970-1971 modifications were made . This reinstalled impeller/shaft assembly had operated for approximately two months when the seal failure occurred on September 16, 1984.

A site visit was made on October 10, 1984, to review photographs of the failed parts and to review the licensee investigation plan. The plan consisted of sending the pieces related to the failure to Battelle-Columbus Laboratory for analysis. The failed bolts and pins underwent SEM fractography, corrodent identification, tensile testing, hardness testing, and chemical analysis.

The inspector returned to the site on October 16 to examine the failed parts. The high strength drive pins fractured in a brittle manner as would be expected. The stainless steel Type 304 bolts also failed in a brittle mode. As stainless steel Type 304 is quite tough, the brittle failure was suggestive of fatigue. Evidence of fretting on the bolted surface of the hydro bearing indicated excessive side to side movement of the rotating element. The pump wear rings showed that the impeller had been running both off center and dropped down somewhat. Two of the drive pins still intact and two of the bolts with fractured heads were wedged in such a manner as to allow continued rotation of the impeller. Of particular interest was the condition of the bolt threads. An examination of the bolts showed evidence of poor manufacturing practice in that thread surfaces appeared rough and torn. This type of appearance is suggestive of dull tooling during manufacture.

A meeting was held at the site on October 30 for the licensee to report their preliminary findings:

a. No corrodent was found on the failed bolt surfaces, thus eliminating the possibility of an IGSCC mode of failure.

b. Fatigue cracks originated at cold worked sites and progressed in a fatigue mode until overloading caused a final ductile fracture. Two drive pins failed by impact loading; the other two pins were bent.

c. Examination of the bolts from the rotating element that was removed earlier in the year with over 10 years of service showed no sign of failure.

d. Pump failure was believed to be due to improper assembly of either the rotating element or the pump.

Available records of the 1971 modification for the failed rotating element were reviewed. The package consisted primarily of weld material Certified Material Test Reports (CMTRs) and Nondestructive Examination (NDE) reports covering the modification and required repairs. No documentation could be located for the failed bolts.

The inspectors reviewed the licensee documentation package for the maintenance activities associated with the reinstallation (completed February 3, 1984) of the rotating element that subsequently failed. The package included procedure PCS-M-22 "Removal and Replacement of Shaft Seal Cartridge" and PCS-M-47 "Primary Coolant Pump Disassembly and Reassembly." These procedures included data sheets showing clearance and alignment measurements taken during the repair. No evidence of improper maintenance practice was noted during the review.

Battelle spectrographic analysis and mechanical testing of the failed bolts and pins showed no irregularities. Scanning electron microscopy showed the striations typical of fatigue on the failed bolt surfaces. The drive pins showed a cleavage mode of failure.

It is postulated that the bolts failed in fatigue due to cyclic loading brought about because of insufficient preload on the bolts. It is believed that the poor condition of the bolt threads caused excessive torque during the assembly of the rotating element in 1971. These conclusions were reported by the licensee during a meeting held on November 9 at the Region III office.

Replacement parts were obtained by Consumers Power Company then remachined and field balanced as necessary. Other parts were repaired. The inspector reviewed the licensee documentation package for maintenance activities covering the pump repair as well as the Byron Jackson activities involving the assembly of the new rotating element. No evidence of improper practice was noted during this review.

The licensee installed special acoustic monitoring equipment to listen for a broken bolt piece that could not be located. No noise was noted on pump start that could have been from the bolt piece. Also, in the event that the piece (approximately ½ pound) is in the bottom of the reactor vessel, the licensee analyzed for this condition and reported that no adverse damage would be experienced due to such an object. Other testing on pump startup included special vibration analyses, flow and coastdown evaluations. No anomalies were identified during the vibration or coastdown evaluations but the pump flow or head curve was slightly lower than expected. In performing PCS flow testing per procedure RT-57, a flow deficiency of 0.63 percent was determined. Hence, the thermal margin/low pressure reactor trip was increased by 14 psi to meet Technical Specification 3.1.1.C.

The inspector observed pump operating parameters in the main control room on December 5, 1984, after two weeks of plant operation with the repaired pump. The parameters for all four pumps appeared normal with all pump seal pressures at the proper level and holding steady. The P-50C pump had the lowest shaft vibration indicated (2.5 mils displacement). (The inspector noted that this is approximately equal to "shaft runout" measured during pump assembly and, hence, may not be the result of actual vibration due to the vibration measurement technique.)

Due to the short operating life associated with the pump impeller failure, involvement of the other pumps with over ten years of successful service has been ruled out. Also, since it appears that the cause of the problem was related to an activity that took place thirteen years ago during vendor modification of the pump impeller, and since no other failure of this type has occurred, the event appears to be an isolated case.

The inspector found the licensee's immediate response to this event and subsequent recovery activity fully responsive to nuclear safety concerns and regulatory requirements.

No deviations or items of noncompliance were identified.

3. Exit Interview

The inspector met with licensee representatives on several occasions during the inspection, both formally and informally. A final meeting was held at the site on December 5, 1984 with those denoted in Paragraph 1. The licensee indicated that a detailed metallurgical report would be available from the Battelle-Columbus Laboratory soon and that the final report to be prepared by Consumers Power Company should be available around February 1985.