UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D. C. 20555-0001

May 11, 2001

NRC INFORMATION NOTICE 2001-06: CENTRIFUGAL CHARGING PUMP THRUST BEARING DAMAGE NOT DETECTED DUE TO INADEQUATE ASSESSMENT OF OIL ANALYSIS RESULTS AND SELECTION OF PUMP SURVEILLANCE POINTS

Addressees

All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees that inadequate assessment of pump oil analysis results, combined with surveillance testing which does not monitor all relevant pump operating conditions, may allow severe pump degradation to go undetected. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid problems. However, the suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

On June 19, 2000, while disassembling the C charging/safety injection pump (CSIP) to replace a mechanical seal, Shearon Harris Nuclear Plant (SHNP) personnel discovered significant damage to the outboard thrust bearing. Further examination revealed that the babbitt material on the bearing shoes of this multi-pad thrust bearing had melted and re-solidified within the thrust bearing cage area. On both the shoes and the sleeve of the thrust bearing, radial wear in the direction of normal pump rotation was indicative of metal-to-metal contact between the two surfaces. The inboard radial bearing and shaft also had minor wear. SHNP stated in a licensee event report (Reference 1) that the most probable cause of the damage was a momentary loss of lubrication flow to the outboard thrust bearing. An inadequate fill-and-vent of the pump, which may have caused a momentary increase in the axial thrust on the outboard thrust bearing, was also given as a potential root cause.

Elemental analysis of a routine pump bearing oil sample taken on September 19, 1999, using a direct current plasma (DCP) spectrometer, revealed a 40-fold increase in the particle count in the range of 5 to 10 microns over the previous sample taken on May 11, 1999. (The particle count increased from 15,800 to 660,000 counts per 100 milliliter sample.) All other tested

parameters were normal. SHNP reviewed the Electric Power Research Institute (EPRI) Lubrication Guide (Reference 2) and concluded that the size range of these wear particles was consistent with benign wear. The bearing oil in the CSIP was replaced on December 21, 1999, and SHNP continued sampling at 6-month intervals. The next oil sample, taken on February 23, 2000, also showed a high particle count in the 5 to 10 micron range. Trace amounts of iron and tin were also detected for the first time. The analysis of another oil sample taken on June 18, 2000, found that the levels of all parameters were similar to the levels in the February 23, 2000, sample.

Each CSIP at SHNP is a Pacific Model 2½ RLIJ, 11-stage, centrifugal pump manufactured by Flowserve Corporation, formerly Ingersoll-Dresser Pump Company. The C CSIP is the standby pump. During the period in which high particle counts in the three oil samples were detected, the C pump was intermittently in service to support plant operations. Surveillance testing, as required by the SHNP inservice testing program and the SHNP Technical Specifications, was performed on the C pump during this period. Inservice tests, including vibration measurement, were conducted during plant operation on November 13, 1999, and January 3, 2000, with the pump operating at the normal charging flow rate of approximately 90 gallons per minute (gpm). Performance data from both tests indicated the C CSIP met the established pump hydraulic and mechanical acceptance criteria in the American Society of Mechanical Engineers (ASME) Code for Operation and Maintenance of Nuclear Power Plants (OM Code), and no adverse trends were noted. On April 23, 2000, a refueling outage test to satisfy the SHNP technical specifications was performed successfully, with the pump achieving a flow rate of 609 gpm.

Subsequent to the discovery of the severely degraded outboard pump thrust bearing, discussions with the pump manufacturer revealed that at flow rates between approximately 250 and 600 gpm, the net axial thrust of each SHNP CSIP pump is in the direction of the outboard thrust bearing. Therefore, SHNP concluded that during normal plant operation and surveillance testing, the outboard thrust bearing had been either not loaded or only lightly loaded. In addition, SHNP could not assess the capability of the C CSIP to perform its function during a small-break, loss-of-coolant accident, in which the pump axial thrust would have fully loaded the outboard thrust bearing.

In response to an NRC notice of violation (Reference 3), SHNP described corrective steps either completed or in progress to address this issue. These included (1) counseling operators on consequences of improper pump fill-and-vent of the CSIP, (2) establishing oil analysis criteria for increased lubricant particle counts, (3) reinforcing expectations for disposition of abnormal indications, (4) sampling CSIP lubricating oil quarterly instead of semi-annually, (5) revising the maintenance procedure to ensure that the CSIP lubricating oil system will function as expected, and (6) implementing a design modification to install temperature and vibration proximity probes on each CSIP.

NRC Requirements and Industry Guidance and Practices on Pump Condition Monitoring

The current requirements for inservice testing of safety-related pumps are specified in Section 50.55a of Title 10 of the Code of Federal Regulations (10 CFR 50.55a), "Codes and Standards." For plants which are required to update their inservice testing (IST) programs after September 22, 2000, which is one year after the recent change to 10 CFR 50.55a (Reference 4), Subsection (b)(3) requires that safety-related pumps be tested to the 1995 Edition and the 1996 Addenda of the ASME OM Code. The Code requires that safety-related pumps be tested biennially at ±20% of their design flow rate, and every three months at specific reference points. Overall vibration measurements of each pump bearing are taken as specified by the Code. The SHNP IST program is in accordance with an earlier version of the Code, which requires pump testing to be conducted every three months at reference points of operation readily duplicated during subsequent tests. Pump hydraulic performance is assessed by comparing current performance with reference values established when the pump is known to be operating acceptably. Pump mechanical performance is assessed like hydraulic performance, unless the specified multiple of the measured overall vibration reference value exceeds the absolute vibration acceptance criterion.

Neither the Code nor the regulations require any specific pump condition monitoring activities to be performed on safety-related pumps. However, the NRC has observed during inspection activities that many US commercial nuclear power plants have some type of condition monitoring program for their rotating machinery. These programs usually include both safety-related and non-safety-related equipment. Because no regulations cover these programs, the testing performed, the examinations completed, and the acceptance criteria used for each condition monitoring activity vary widely.

The EPRI Lubrication Guide includes information on the testing and analysis of lubricants. The guide identifies particle size and wear-metal content as key properties to analyze. The guide also provides "classic" warning limits for certain measured properties. The guide does not recommend a specific warning limit for particle count. However, the guide emphasizes trending critical properties of a specific application and establishing appropriate warning limits. When these limits are exceeded and the results are verified, the guide recommends oil replacement and further study if necessary.

The NRC has authorized alternatives to the Code vibration requirements based on the performance of pump condition monitoring activities. For example, as part of an alternative to the Code vibration acceptance criterion, one facility committed to implement a plant-specific pump condition monitoring program for certain safety-related pumps. The NRC has determined that this proposed alternative demonstrates an acceptable level of quality and safety.

Discussion

A key factor in the failure to discover the damaged bearing before disassembly was not actively pursuing the root cause of the abnormally high particle count in the September 19, 1999, oil sample. The EPRI guide implies that particles less than 10 microns in size are generated from "benign wear." The guide does not discuss the significance of changes in wear particle concentration. However, the guide does discuss trending of parameters. SHNP performed spectroscopic analysis of each sample and trended the results of these tests. The low weight percent of the wear particles was apparently the reason why the elemental analysis did not detect the presence of bearing material. Ferrography and electron microscopic scan examination were conducted after the discovery of the bearing degradation and therefore were not a factor in diagnosing the elevated particle count. SHNP elected to continue with a routine oil sampling schedule despite the high particle count and the lack of a plausible root cause for this condition. A more aggressive oil sampling schedule (e.g., weekly) would likely have revealed the severely degraded outboard thrust bearing several months before the pump was disassembled.

Inservice and technical specification surveillance testing did not indicate that the outboard thrust bearing was severely damaged. The purpose of pump inservice testing is to identify degradation before the pump's performance of its safety-related function is impaired. For the charging pumps at the SHNP, the purpose of technical specification testing is to verify that the pump will deliver a specific flow at the required total developed head. The failure of both tests to indicate bearing degradation appears to have biased the decision to not investigate the elevated particle count.

Information provided by the vendor revealed a reversal in the direction of the pump axial force as a function of the pump flow rate. This pump design characteristic was unknown to SHNP personnel before they discovered the severely degraded bearing and then talked with the vendor. The Code does not require SHNP to account for this design condition through testing. The technical specification full flow test after the first detection of the high particle count neither detected this condition nor caused a catastrophic failure of the pump. This issue illustrates that the assessment of safety-related pump performance is dependent not only on verifying successful surveillance testing, but also on understanding (1) pump and system design and performance characteristics, (2) performance testing results, and (3) the results of condition monitoring activities and their correlation with known pump design characteristics and performance test results.

Generic Implications

If trends of condition monitoring data are not actively investigated when they deviate from an established baseline, a licensee may overlook significant pump degradation that is not detected by performance testing.

This information notice requires no specific action or written response. If you have any questions about this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Attachments:
1. List of References
2. List of Recently Issued Information Notices

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References

1. Shearon Harris Nuclear Power Plant Unit 1, Docket Number 50-400, Licensee Event Report 2000-007-01, “Technical Specifications Violation Due to Inoperable Charging Safety Injection Pump,” dated March 12, 2001.

2. NP-4916-R2, Electric Power Research Institute/Nuclear Maintenance Applications Center Lubrication Guide, Revision 2, published February 1995.

3. Shearon Harris Nuclear Power Plant Unit 1, Docket Number 05000-400, Reply to Notice of Violation (NRC Inspection Report Numbers 50-400/00-03, 50-400/00-10) dated March 2, 2001.

4. Federal Register, Volume 64, Number 183, “Industry Codes and Standards; Amended Requirements,” (10 CFR Part 50), issued September 22, 1999.

LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
2001-05	Through-Wall Circumferential Cracking of Reactor Pressure Vessel Head Control Rod Drive Mechanism Penetration Nozzles at Oconee Nuclear Station, Unit 3	04/30/01	All holders of operating licenses for pressurized water nuclear power reactors except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel
2001-04	Neglected Fire Extinguisher Maintenance Causes Fatality	04/11/01	All holders of licenses for nuclear power, research, and test reactors and fuel cycle facilities
2001-03	Incident Reporting Requirements for Radiography Licensees	04/06/01	All industrial radiography licensees
2001-02	Summary of Fitness-for-Duty Program Performance Reports for Calendar Years 1998 and 1999	03/28/01	All holders of operating licenses for nuclear power reactors, and licensees authorized to possess or use formula quantities of strategic special nuclear material (SSNM) or to transport formula quantities of SSNM
2001-01	The Importance of Accurate Inventory Controls to Prevent the Unauthorized Possession of Radioactive Material	03/26/01	All material licensees
2000-17, Supp. 2	Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V.C. Summer	02/28/01	All holders of operating licenses for nuclear power reactors except those who has ceased operations and have certified that fuel has permanently removed from reactor vessel
2000-22	Medical Misadministrations Caused by Human Errors Involving Gamma Stereotactic Radiosurgery (GAMMA KNIFE)	12/18/00	All medical use licensees authorized to conduct gamma stereotactic radiosurgery treatments

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CP = Construction Permit