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

October 26, 1994

NRC INFORMATION NOTICE 94-76: RECENT FAILURES OF CHARGING/SAFETY INJECTION PUMP SHAFTS

Addressees

All holders of operating licenses or construction permits for pressurized water reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to alert addressees to recent failures of charging/safety injection pump shafts at facilities designed by the Westinghouse Electric Corporation (Westinghouse). It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Background

At Westinghouse-designed facilities, charging/safety injection pumps have three functions: (1) to deliver seal injection flow to the reactor coolant pumps, (2) to deliver makeup water flow to the reactor coolant system, and (3) to deliver high head safety injection and recirculation flow to the reactor coolant system during and after a loss-of-coolant accident. During normal operation, one of two, or in some cases, one of three pumps is always in operation to deliver seal injection and makeup water flow. The loss of an inservice charging/safety injection pump creates a condition that may challenge reactor coolant pump seal integrity and, if makeup water flow is not restored in a timely manner, can result in a loss of coolant inventory.

On February 29, 1980, the NRC issued IN 80-07, "Pump Shaft Fatigue Cracking," to alert recipients to failures of charging/safety injection pump shafts that occurred during the 1970s. All of the charging/safety injection pump shafts addressed in that notice were procured by Westinghouse from the Pacific Pump Division of Dresser Industries (now Ingersoll-Dresser Pump Co). Actions taken at that time to correct the problem included design modifications, changes in the heat treatment of the shaft material, and the use of formed cutting tools during fabrication. Also, abnormal operation of the pumps such as operation with a partial or complete loss of fluid or with high vibration present was found to be a significant contributor to the shaft failures. The Westinghouse Nuclear Service Division issued Technical Bulletins TB-77-9, TB-78-1, and TB-79-6, to provide guidance on vibration monitoring, operation and maintenance of the pumps, and allowable vibration amplitude limits.

9410200153 updated on 11/1/94 PDR I&E Notice -94-076 941026

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Recent events indicate that failures of charging/safety injection pump shafts continue to be a problem.

Description of Circumstances

Sequoyah Unit 1

On February 18, 1991, plant operators for Sequoyah Unit 1 received indications of decreasing flow and increasing motor current on charging pump 1B-B. When efforts to restore full flow failed, they declared the pump inoperable and began shutting down the reactor as required by plant technical specifications. Charging pump 1B-B had been in operation for several months and had shown no previous signs of degradation. The licensee disassembled the pump, found heavy wear on the impeller shoulders and the balance drum, and found a 280-degree crack in the shaft near the 11th stage impeller. Westinghouse analyzed the shaft and determined that the crack had been in the shaft for several months (possibly years) and that the rotating element was of the improved type referred to in IN 80-07. The licensee replaced the rotating element and, after testing the pump successfully, returned the pump to service. [Licensee Event Report (LER) 50-327/91-003]

Callaway

On February 2, 1992, the Union Electric Company Callaway Plant was at power and charging pump B was in service to support operations. Plant operators received indications of zero flow in the charging header and at the reactor coolant pump seal. The operators placed charging pump A in service to restore normal flow, and pump B tripped. Plant personnel inspected pump B and found that the shaft had sheared on the outboard end between the balance drum lock nut and balance drum mating area. The licensee documented the failure in Suggestion Occurrence Solution 92-103 and replaced the failed shaft.

Shearon Harris

On March 18, 1993, operators at the Shearon Harris plant received indications of a shaft failure on charging/safety injection pump B. The indications were high motor current, low charging flow, and low pump discharge pressure. The operators secured pump B from service and placed pump A in service. Plant personnel uncoupled the pump from the motor and found that the pump shaft had sheared under the balancing drum lock nut. This was the same location as in three failures that occurred in the 1970s. (LER 50-400/93-005)

D.C. Cook Unit 2

In July 1993, at D.C. Cook Unit 2, a charging pump failed a surveillance test when it could not deliver the required 454 liters [120 gallons] per minute. The rotating element in that pump had been installed in 1987. The licensee disassembled the pump and found a 10 centimeter [4 inch], 180 degree circumferential crack through the number 9 impeller shaft keyway. Smaller cracks were found in two other impeller keyway areas. (LER 50-316/93-006)

Braidwood Unit 1 and Sequoyah Unit 2

The NRC staff has received information on two other recent failures of charging/safety injection pump shafts: (1) on September 15, 1993, at the Braidwood Nuclear Station Unit 1 (Braidwood), a charging/safety injection pump shaft sheared between the 10th and 11th stage impellers, and (2) on February 7, 1994, at Sequoyah Unit 2, a charging\safety injection pump shaft failed, resulting in a reactor shutdown as required by plant technical specifications. The licensee for Braidwood replaced the pump shaft and documented the failure on Problem Investigation Report 456-200-93-03600. The licensee for Sequoyah reported that the affected pump had not exhibited any indication of degradation before the shaft failure and that, similar to many of the other shaft failures, the shaft had failed near the location of the balancing drum lock nut. (LER 50-328/94-002)

Discussion

Charging/safety injection pumps are important for normal plant operation and for core cooling during accidents such as a small break loss-of-coolant accident. For most of the failure events described above, determination of the root cause of the failure was inconclusive. However, the operational histories of many of the failed shafts showed that they had been operated with void formation, gas entrainment, or other abnormal conditions within a few years of the failure. Operation of the pumps under these conditions may have caused or contributed to the later failure of the shafts. Avoiding operation of charging pumps under abnormal conditions and maintaining vibration levels within manufacturer recommendations may increase pump reliability. To increase the benefit of predictive maintenance programs, Westinghouse recommends that pump vibrations be monitored at least monthly; preferably, every two weeks. This is more frequent than is required by Section XI of the ASME Boiler and Pressure Vessel Code. Westinghouse will provide recommended vibration limits upon request.

Industry experience in detecting shaft failures in pumps such as the reactor coolant pump and the recirculation pump is relevant to monitoring programs of charging/safety injection pumps because the precursors to shaft failure are similar. For those pumps, monitoring phase angles as well as monitoring vibration amplitude is considered to be important in detecting shaft degradation. These data are routinely trended by some licensees for detection of impending shaft failures.

A description of the analyses and conclusions for some of the above events follows:

Westinghouse evaluated seven possible root causes for the shaft failure at Callaway, including material defects, design flaws, errors in fabrication or processing, assembly or installation defects, off-design or unintended service conditions, maintenance deficiencies, and improper operation. Westinghouse concluded that the shaft failure was most likely the result of a 1986 event in which the pump had experienced a loss of suction water flow for approximately seven minutes. The loss of suction flow increased the vapor-to-liquid ratio in the pump and caused a dynamic imbalance. Events of this type could cause immediate pump failure or cause cyclic fatigue damage that could lead to premature shaft failure at a later date.

A gas entrainment event that occurred on August 20, 1990, was determined to be the probable cause of the shaft failure at Sequoyah Unit 2. Problems caused by gas entrainment are discussed in NRC Information Notice 88-23, "Potential for Gas Binding of High-Pressure Safety Injection Pumps During a Design Basis Accident," and its supplements.

Westinghouse considers an operational phenomenon, such as gas entrainment, may have led to the shaft failure at Shearon Harris, although the licensee found no evidence of gas pockets in the charging system. In May 1991 (two years before the shaft failure), the licensee reported to the NRC that the charging system had been in a degraded condition during the previous operating cycle. An NRC Special Inspection Team reviewed the event and determined that several water hammer events could have occurred in the system as a result of weaknesses in the design of the alternate minimum flow system. The NRC issued IN 92-61, "Loss of High Head Safety Injection," and its supplement regarding that event. Another concern at Shearon Harris was the fact that the A and B charging/safety injection pumps are alternated at approximately 2-week intervals. Therefore, each pump is started about 25 to 30 times each year. Westinghouse believes the high number of starts also could contribute to early shaft failure. Problems associated with excessive pump starts include galled wear rings, increased vibration, and decreased pump performance. However, Westinghouse concluded that the available data were insufficient to directly link the failure of the shaft to the high number of pump starts.

Although Westinghouse could not conclusively determine the root cause of the shaft failure at Shearon Harris, Westinghouse made recommendations which could help prevent or detect impending shaft failures. Westinghouse suggested that the licensee conduct a detailed review of the possibility that gas could become entrained in the charging pump suction piping and the cross connects to other systems. Westinghouse also recommended that, when the rotating element of the pump is replaced, consideration be given to installing the latest shaft design which has an improved one-piece balance drum lock nut. Westinghouse included recommendations for vibration monitoring in Westinghouse Technical Bulletin TB-79-6. Westinghouse has not specified a limitation on the number of pump starts but recommends that pump starts be minimized to maintain pump reliability.

In addition to the industry actions described above, Westinghouse and the Westinghouse Owners Group (WOG) are implementing a program to address these pump shaft failures. The program includes: (1) a survey of WOG member utilities for pump service operating history data, (2) a pump design review, and (3) a shaft material enhancement evaluation. The program is intended to identify any weaknesses in design, maintenance, or operation of the pumps in order to improve shaft reliability.

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

Brian Grimes

Brian K. Grimes, Director
Division of Project Support
Office of Nuclear Reactor Regulation

Technical contact: D. Roberts, RII
(919) 362-0601

Attachment:
List of Recently Issued NRC Information Notices

Attachments filed in Jacket

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
93-60, Supp. 1	Reporting Fuel Cycle and Materials Events to the NRC Operations Center	10/20/94	All 10 CFR Part 70 fuel cycle licensees.
94-75	Minimum Temperature for Criticality	10/14/94	All holders of OLs or CPs pressurized-water reactors (PWRs).
94-74	Facility Management Responsibilities for Purchased or Contracted Services for Radiation Therapy Programs	10/13/94	All U.S. Nuclear Regulatory Commission Medical Licensees.
94-73	Clarification of Criticality Reporting Criteria	10/12/94	All fuel fabrication facilities.
94-72	Increased Control Rod Drop Time from Crud Buildup	10/05/94	All holders of OLs or CPs for pressurized water reactors
94-71	Degradation of Scram Solenoid Pilot Valve Pressure and Exhaust Diaphragms	10/04/94	All holders of OLs or CPs for boiling water reactors (BWRs).
94-70	Issues Associated with Use of Strontium-89 and Other Beta Emitting Radiopharmaceuticals	09/29/94	All U.S. Nuclear Regulatory Commission Medical Licensees.
94-69	Potential Inadequacies in the Prediction of Torque Requirements for and Torque Output of Motor-Operated Butterfly Valves	09/28/94	All holders of OLs or CPs for nuclear power reactors.
94-68	Safety-Related Equipment Failures Caused by Faulted Indicating Lamps	09/27/94	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit

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Original signed by
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NAME	DRoberts*	JRJohnson**	BBoger*
DATE	08/18/94	05/27/94	08/19/94

OFFICE	EMEB:DE	C/EMEB:DE	D/DE:NRR
NAME	JRajan*	RWessman*	BWSheron*
DATE	08/22/94	08/26/94	08/30/94

OFFICE	TECHED:RPB	OGCB:DORS:NRR	C/OGCB:DORS:NRR	D/DOPS:NRR
NAME	JMain*	JBirmingham*	ELDoolittle*	BKGrimes
DATE	07/20/94	08/17/94	09/08/94	10/21/94

OFFICIAL DOCUMENT NAME: 94-76.IN

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