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

April 5, 2005

NRC INFORMATION NOTICE 2005-08: MONITORING VIBRATION TO DETECT CIRCUMFERENTIAL CRACKING OF REACTOR COOLANT PUMP AND REACTOR RECIRCULATION PUMP SHAFTS

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 vessel.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to alert addressees to the importance of timely detection of circumferential cracking of reactor coolant pump (RCP) and reactor recirculation pump (RRP) shafts to minimize the likelihood of consequential shaft failures.

It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, the suggestions in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

General Electric (GE) Nuclear Services Information Letter (SIL) 459-S2, issued October 21, 1991, informed GE boiling water reactor (BWR) owners of shaft cracking in RRPs. The root cause was determined to be fatigue initiated by thermal stresses that, combined with mechanical stresses, caused cracks to propagate. GE recommended countermeasures including shaft vibration monitoring, inspection of shafts with greater than 80,000 hours of service, and measures to reduce mechanical and thermal stresses.

At Hope Creek, RRPs had accumulated over 130,000 hours of service without pump shaft inspections. The licensee had operated the B RRP for several refueling cycles with vibration levels approaching vendor limits. During this time, the licensee also identified failed and degraded RRP seals and concluded that the most likely causes of the failed and degraded RRP seals were a possible bow in the pump shaft and low reliability of the seal purge system.

ML050730093

The licensee's decision to restart following the fall 2004 refueling outage without correcting this condition led to heightened public interest and prompted a close NRC review. The staff evaluated site-specific technical details, related domestic and international operating experience, and the generic safety aspects of vibration-related shaft and seal failure. Circumferential cracking of RCP and RRP shafts had previously been reported at several facilities including Sequoyah, Palo Verde, St. Lucie, and Grand Gulf. In addition, reactor coolant pump shafts at Crystal River separated completely during operation on two occasions (see IN 86-19 and IN 89-15).

The staff evaluated the licensee's determination that the Hope Creek unit could be safely returned to power with the existing pump shaft and the interim compensatory measures implemented to provide reasonable assurance that a shaft failure could be detected in its incipient stage and operators would take prompt action to prevent the occurrence of a potential shaft and seal failure. The licensee committed to (1) replace the B pump shaft at the next outage of sufficient duration and to (2) establish a comprehensive program of enhanced continuous vibration monitoring to ensure timely detection of circumferential crack propagation with proceduralized contingency actions for plant operators to act promptly at specified administrative vibration limits to reduce pump speed or shut the pump down completely. The same monitoring regime was implemented for the A RRP.

The Hope Creek licensee implemented a program to continuously monitor the synchronous speed (1X) vibration amplitude, two times synchronous speed (2X) vibration amplitude, 1X phase angle, and 2X phase angle. These parameters provide a more sensitive leading indicator of circumferential crack initiation and propagation giving the operators enough time to respond. Alarm limits were established using the ASME OM standard, "Reactor Coolant and Recirculation Pump Condition Monitoring."

GE SIL 459 indicates that all Byron Jackson (now Flowserve) RRP shafts inspected have shown some degree of thermally induced cracking. The cracking occurs near the pump thermal barrier where the cold seal purge system water mixes with the hot reactor coolant water. The cracks initiate as axial cracks in the pump shaft. Axial cracks are generally benign, grow slowly, and do not affect the operation of the pump. However, given sufficient mechanical loads, the axial cracks can change direction and propagate circumferentially. The time it takes to transition from slow-growing axial cracks to more rapidly growing circumferential cracks depends on the magnitude of the mechanical loads on the pump shaft. It could take years. On the other hand, circumferential shaft cracking can propagate rapidly and, if not detected early, may result in complete severance of the shaft.

Circumferential shaft cracking or shaft separation could result in pump damage and degradation or failure of the pump seal package resulting in leakage of reactor coolant through clearances around the upper portion of the pump shaft. However, at Crystal River - where the only two instances of shaft failure occurred at domestic nuclear power plants - there was no evidence of seal degradation. A loss-of-coolant accident can occur if leakage through the seals of a RRP or RCP exceeds the capacity of the normal makeup systems. Thus circumferential shaft cracking that leads to shaft or seal failure is a safety concern.

As noted above, vibration-monitoring systems are available to detect circumferential cracking of pump shafts. As circumferential cracks propagate, the stiffness of the pump shaft changes. These changes are detectable through changes in the pump vibration signature prior to shaft failure. Although overall pump vibration limits are necessary for assessing gaps and clearances in the pump, they are not the most appropriate indicator of shaft cracking. Monitoring the 1X and 2X steady-state vectors (1X and 2X amplitudes and phase angles) provides a better indication of changes in shaft integrity resulting from circumferential crack propagation.

Licensees should be alert to the possibility of circumferential RCP or RRP shaft cracking and should evaluate the information in this IN and determine what actions, if any, are prudent to provide early detection of circumferential shaft cracking and prevent failure of RRP or RCP shafts and shaft seals.

GENERIC IMPLICATIONS

A significant number (about half) of the BWR RRP pump shafts currently in service are older and have more hours of operation than those at Hope Creek and many have not been inspected as recommended in GE SIL 459-S2.

About a half-dozen BWR RRPs were identified as having higher vibration levels than Hope Creek. Such issues would not necessarily be reported to the NRC. The staff contacted three BWR licensees whose plants had been reported to have higher vibration levels than Hope Creek. The three plants included Susquehanna Units 1 and 2, Peach Bottom Units 2 and 3, and Browns Ferry Units 2 and 3. The staff discussed with each licensee how it monitors pump vibration, the vibration acceptance criteria used, and why the current vibration levels are acceptable. These licensees indicated that they have either replaced their pump shafts (or will in the near future) or are taking steps to monitor RRP vibration and have established acceptance criteria to detect anomalous behavior.

Operating experience suggests that pressurized water reactor (PWR) RCPs are not immune to vibration-related shaft and seal failure concerns similar to BWR RRP concerns. PWR RCP seal failure can be more safety significant than BWR RRP seal failure because (1) PWR reactor coolant systems operate at higher pressures, increasing the differential pressure across the pump seals and (2) PWR RCPs, unlike BWR RRPs, typically can not be isolated from the reactor coolant system following a seal failure. In addition, while a number of BWR RRP shafts have cracked, several PWR RCP shafts have completely severed.

CONTACT

This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contact(s) listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

/RA/
Patrick L. Hiland, Chief
Reactor Operations Branch
Division of Inspection Program Management
Office of Nuclear Reactor Regulation

Technical Contacts: William Poertner, NRR
(301) 415-5787
E-mail wkp@nrc.gov

Ross Telson, NRR
(301) 415-2256
E-mail rdt@nrc.gov

Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under Electronic Reading Room/Document Collections.