UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

November 23, 2007

NRC INFORMATION NOTICE 2007-37: BUILDUP OF DEPOSITS IN STEAM GENERATORS

## ADDRESSEES

All holders of operating licenses or construction permits for pressurized water reactors except those that have permanently ceased operations and who 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 potential for deposits to accumulate in their steam generators and potentially affect steam generator performance and tube integrity. The NRC expects that recipients of this IN will review the information for applicability to their facilities and consider taking actions, as appropriate, to avoid similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

## DESCRIPTION OF CIRCUMSTANCES

Operating Experience at a Foreign Reactor

Between 2004 and 2006, three primary-to-secondary leaks occurred at the Cruas Nuclear Plant, a multi-unit site in France. The last primary-to-secondary leak occurred at Cruas Unit 4 in February 2006 (Autorité de Sûreté Nucléaire 2006 Annual Report, http://annual-report.asn.fr/PDF/nuclear-power-plants-EDF.pdf), and it was detected through the use of nitrogen-16 radiation monitors. The leak rate increased from very low levels to approximately 3 gallons per minute [600 liters per hour] in 12 minutes.

All three leaks were a result of a circumferential crack in the tube at the location where the tube passes through the uppermost tube support plate (TSP). All three tubes were near the center of the tube bundle near an area where no tubes are installed. This tube-free area was intended to facilitate secondary water/steam flow into the interior of the tube bundle. The U-bend region of the affected tubes did not have any anti-vibration bar support since the radii of these U-bends were small.

The cause of the cracks was determined to be high cycle fatigue as a result of flow-induced vibration. The tubes became susceptible to vibration and fatigue as a result of the buildup of deposits on the secondary side of the steam generator which changed the flow conditions in the center of the tube bundle. The deposits had blocked water/steam flow through the quatrefoil-shaped holes in the TSPs, forcing more water/steam into the center of the tube

bundle. The extent of the hole blockage was estimated based on visual examinations, analysis of eddy current test results, and evaluation of the wide range feedwater level gauge readings. High levels of deposits were determined to be present based on these inspections and analyses.

Contributing factors to the buildup of the deposits were determined to be low secondary side pH (less than 9.6), chemical intrusions (from main condenser cooling water leakage into the secondary system), and the TSP hole design (quatrefoil-shaped holes).

To address this problem, several corrective actions came under consideration, including evaluating the level of TSP hole blockage, removing the deposits through chemical cleaning, changing the chemistry conditions on the secondary-side of the plant to reduce the rate of buildup of deposits, analyzing the consequences of the deposits on the flow through the steam generator, and analyzing the stresses that could be imposed on the TSP during transients and accidents as a result of the hole blockage.

Operating Experience at a U.S. Reactor

In the early 1990s, steam generator water level oscillations were observed at Surry Power Units 1 and 2, near Newport News, Virginia. Due to the severity of these water level oscillations, the units operated at reduced power levels for varying periods of time. The cause of the steam generator water level oscillations was severe deposit buildup in the TSP quatrefoil-shaped holes. The licensee corrected the problem by performing chemical cleaning on all steam generators at both units to reduce the extent of deposits.

**BACKGROUND**

Corrosion products can accumulate in the secondary side of the steam generator as a result of the gradual erosion and corrosion of secondary side components in a pressurized water reactor. This accumulation of corrosion products results in the buildup of deposits on the tubes, tubesheets, and other secondary side steam generator structures (including the holes through which the tubes pass).

Harmful contaminants can concentrate in these deposits and result in corrosion of the steam generator tubes. In addition, these deposits can affect the thermal performance of the steam generator (i.e., the ability to transfer heat from the primary-to-secondary side of the steam generator) and the thermal hydraulic characteristics of the steam generator (by changing the flow patterns within the steam generator).

As a result of the negative effects of these deposits, plant operators in the U.S. frequently remove the deposits from the top of the tubesheet by a process referred to as sludge lancing. Operators also occasionally remove these deposits from other areas in the steam generator through chemical cleaning processes.

High cycle fatigue cracking caused by flow-induced vibration have been observed in U.S. steam generators. Fatigue cracking in steam generators with U-shaped tubes was the subject of NRC Bulletin 88-02, “Rapidly Propagating Fatigue Cracks in Steam Generator Tubes.” This cracking

occurred, in part, because of two factors: (1) There was denting of the tubes at the tube-to-TSP intersection and (2) non-uniform anti-vibration bar penetration into the tube bundle caused locally high flow velocities. This cracking occurred in tubes with small U-bend radii. Fatigue cracking in large radius U-bends was discussed in NUREG-1604, "Circumferential Cracking of Steam Generator Tubes." Fatigue cracking in steam generators with straight tubes has also been observed in the U.S. This cracking is associated with localized high velocities near a tube-free lane region in the steam generator.

**DISCUSSION**

Extensive deposit buildup in the TSP holes can increase the vibration of the tubes and potentially lead to fatigue cracking of the tube. Deposits can also change the loading (stresses) on the TSPs during transients and design basis accidents (e.g., a steam line break). Extensive deposit buildup in the tube support holes can change the secondary water recirculation rate and may result in water level oscillations within the steam generator.

The extent to which deposits can buildup in the steam generator (including the tube support holes) will vary from unit to unit. It is a function not only of the tube support configuration (e.g., lattice grid, round hole, quatrefoil-shaped holes), but also of the design and operation of the secondary side of the plant. Low secondary side pH levels may increase the corrosion rate on the secondary side of the plant and lead to more impurity transport to the steam generators. Chemical intrusions (e.g., from main condenser leakage) may also increase the transport of impurities into the steam generator. The more impurities that enter the steam generator, the more likely that deposits will buildup on the secondary side of the steam generator.

The potential for fatigue cracking of the steam generator tubes also varies from unit to unit. It depends on how the tubes are supported and the secondary side flow conditions (which can be affected by the buildup of deposits in the steam generator).

Operating experience demonstrates that once initiated, high cycle fatigue cracks can rapidly propagate over periods ranging from hours to days to complete severance of the tube. As discussed in NRC Bulletin 88-02, enhanced primary-to-secondary leakage monitoring can be an effective tool at reducing the potential for a tube rupture.

Although there is no specific requirement for licensees to monitor, assess, or remove deposit buildup, there are requirements for licensees to maintain steam generator tube integrity. These integrity requirements are contained, in part, in plant technical specifications. Therefore, it is important to assess the deposit buildup in a steam generator and the effects that deposits will have on steam generator performance and tube integrity during normal operation and design basis accidents. Promptly identifying and removing significant deposit buildup may prevent a loss of tube integrity and may improve the thermal performance of the steam generator.

**CONTACT**

This information notice does not require any specific action or written response. Please direct any questions about this matter to the technical contact listed below.

***/RA by TQuay for/***

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

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