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

October 31, 2001

NRC INFORMATION NOTICE 2001-16: RECENT FOREIGN AND DOMESTIC EXPERIENCE WITH DEGRADATION OF STEAM GENERATOR TUBES AND INTERNALS

Addressees

All holders of operating licenses for pressurized-water reactors (PWRs), 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 inform addressees about findings from recent inspections of steam generator tubes and secondary-side internal components and structures. 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

The NRC reported the degradation of steam generator tubes in several generic communications including Information Notice (IN) 96-38, "Results of Steam Generator Tube Examinations"; IN 97-26, "Degradation in Small-Radius U-Bend Regions of Steam Generator Tubes"; IN 97-49, "B&W Once-Through Steam Generator Tube Inspection Findings"; IN 97-88, "Experiences During Recent Steam Generator Inspections"; and Regulatory Issue Summary 2000-22, "Issues Stemming From NRC Staff Review of Recent Difficulties Experienced in Maintaining Steam Generator Tube Integrity." In addition, the NRC reported the degradation of steam generator secondary side structures in IN 96-09, "Damage in Foreign Steam Generator Internals"; IN 96-09 Supplement 1, "Damage in Foreign Steam Generator Internals"; and Generic Letter (GL) 97-06, "Degradation of Steam Generator Internals." This generic communication reports additional experience with the degradation of steam generator tubes and internals.

Description of Circumstances

Foreign Sludge Lancing Experience

In 1998, a foreign reactor was shut down for a refueling outage. At the time of the shutdown, there was no evidence of primary-to-secondary leakage. During the outage, sludge lancing was performed followed by a bobbin coil probe inspection of 100% of the tubes in all four

steam generators. The tube inspections revealed only minor wall thinning. However, during plant startup following the outage, a very small primary-to-secondary leak was observed, and the reactor was shut down to investigate its source.

Subsequent inspections identified several degraded steam generator tubes in the second and third rows of the steam generator tube lane. The degradation consisted of localized loss of the outer surface of the tubes just above the top of the tubesheet. Extensive wall loss in one of these tubes resulted in a pinhole-sized perforation of the tube wall. Although the eddy current examination performed during the refueling outage identified wall thinning in these tubes, the technique was apparently not capable of identifying the very deep, localized degradation found in the leaking tube.

An evaluation determined that the sludge-lancing technique damaged the steam generator tubes. In 1997, a previously used sludge lancing technique was modified to improve tubesheet cleaning and allow longer intervals between lancing operations. The modifications consisted of enlarging the spray nozzles, increasing the water pressure of one of the 90° nozzles, and adding an 8 minute stationary lancing step with the lancing mechanism at the lowest position. Previously, the spray nozzles had been moved continuously up and down. Following the tube leakage event, the facility performed mockup tests using the modified sludge-lancing technique. The testing revealed that no damage to tubes occurred when the water jet angle was exactly 90°; however, it was reported that damage similar to that described above was observed on tubes if the water jet angle deviated from 90°. The extent of the damage increased with the duration of the stationary lancing, the size of the spray nozzle, the water pressure, and the temperature of the water. The testing caused localized wall loss primarily in tubes in the second and third tube rows. No damage was observed in the sixth and higher rows. The mockup test results supported the facility's root cause evaluation.

Degradation of the Calvert Cliffs Unit 2 Tube Support

During the performance of a steam generator secondary-side visual inspection in 1999, Baltimore Gas and Electric Company (BGE) identified degradation at the periphery of the eggcrate tube supports in both steam generators at Calvert Cliffs Nuclear Power Plant Unit 2. In the #21 steam generator, BGE found minor degradation of the eggcrate supports on the hot-leg side at the sixth, seventh, and eighth support elevations. In the #22 steam generator, BGE found more extensive degradation of the eggcrate supports on the hot-leg side at the seventh and eighth support elevations, as well as on the cold-leg side at the sixth support elevation. On the basis of the location and nature of the degradation, BGE concluded that it was caused by erosion-corrosion, similar to, but much less extensive than, that observed at San Onofre Unit 3. (The San Onofre experience is discussed in GL 97-06).

BGE performed an upper bundle flush and sludge lancing of the steam generators during the 1999 inspection outage and adjusted chemistry levels to improve resistance to erosion-corrosion over the following operating cycle. BGE had performed similar secondary-side inspections at Calvert Cliffs Unit 1 in 1996 and 1998 and found no eggcrate degradation.

Possible Degradation in Thermally Treated Alloy 600 Tubes

The steam generators at Turkey Point Units 3 and 4 were replaced in 1982 and 1983, respectively, with steam generators of an improved design. The tubes of the replacement steam generators were made of a more corrosion-resistant material, thermally treated Alloy 600, and were hydraulically expanded (and therefore, subjected to less stress). The quatrefoil tube supports were also more resistant to corrosion, being made of stainless steel.

During a steam generator tube examination in the spring of 2000, the licensee for Turkey Point Unit 3 detected 69 tubes which required plugging. Of the 69 plugged tubes, 41 had volumetric pit-like indications, 15 had inside-diameter-initiated circumferential indications, eight had outside-diameter-initiated circumferential indications, and five had wear indications. Most of these indications were in the hot-leg hydraulic-expansion transition region at the top of the tube sheet. The volumetric and circumferential indications were detected with rotating probes. This was the first time rotating probes were extensively used at Turkey Point Unit 3.

As a result of these findings, the licensee reviewed historical data and industry experience to assess the root causes of the tube degradation. Because of the lack of prior rotating probe inspection data for Turkey Point Unit 3 and the limited number of defects identified by the industry in thermally treated Alloy 600 tubes, the results were inconclusive for the circumferential and volumetric indications.

In a subsequent outage at Turkey Point Unit 4 in the fall of 2000, the licensee detected seven tubes with possible corrosion degradation and plugged these tubes immediately since a qualified depth-sizing technique was not available. Based on the eddy current and ultrasonic examination results in this inspection, the licensee reanalyzed the previous Unit 3 data. The licensee's judgement is that the circumferential and volumetric indications at Unit 3 were false positive and caused by manufacturing anomalies or deposits at the top of tube sheet or by the inspection techniques associated with the rotating probe.

Discussion

Regardless of steam generator design or materials, it is important to effectively monitor the tubes and their support structures to ensure tube structural and leakage integrity are maintained. The operating experience provided above illustrates several important aspects of ensuring steam generator tube integrity.

The sludge lancing experience with the foreign steam generators illustrates the importance of carefully monitoring the tubes after secondary-side "activities." Inspections performed subsequent to chemical and/or mechanical cleaning of the steam generators should be comprehensive to ensure that degradation induced (or exacerbated) by secondary-side activities is detected in a timely fashion to prevent a loss of tube integrity (structural and/or leakage integrity). While the applicability of the foreign sludge lancing experience to domestic facilities may be limited, the experience illustrates the importance of properly qualifying a technique and then verifying that the technique performs as expected.

The degradation of the Calvert Cliffs Unit 2 eggcrate supports illustrates the importance of monitoring secondary side structures/components which may impact tube integrity. If support structures such as eggcrate supports are permitted to excessively degrade, it may result in tube damage through the loss of support to the tube (i.e., tube vibration) and/or through mechanical damage by the introduction of loose material into the steam generator. In the case of Calvert Cliffs, the degradation was not that severe, and the licensee was monitoring the support locations since an analysis of their plant indicated it is one of the most susceptible plants to eggcrate tube support degradation based on feedwater iron transport rates. This analysis is documented in the licensee's response to GL 97-06. With respect to the long-term integrity of these steams generators, the licensee plans to install replacement steam generators at Calvert Cliffs Unit 1 in spring 2002 and at Calvert Cliffs Unit 2 in spring 2003. The replacement steam generators have stainless steel tube supports which are more resistant to erosion-corrosion.

The experience at Turkey Point illustrates the importance of performing comprehensive inspections of steam generator tubes throughout the lifetime of a steam generator regardless of the tube material. The thermally treated Alloy 600 steam generator tubes at Turkey Point are less susceptible to corrosion than mill-annealed Alloy 600 tubes. Nonetheless, the tubes are susceptible to degradation. In the case of Turkey Point Unit 3, the licensee postulated the circumferential and volumetric eddy current signals could be attributable to manufacturing anomalies similar to that observed from pulled tubes removed from Surry and other locations, and for several of the indications detected at Turkey Point Unit 4 where the licensee postulated that possible corrosion degradation was occurring. Without comprehensive inspections early in the life of a steam generator or without metallurgical examination of pulled tubes, evaluations to determine the cause of "new indications" are difficult to perform and are subject to significant judgment. Since the likelihood of steam generator tube corrosion increases as the steam generators age, it is important that special inspection processes and root cause evaluations be comprehensive and conducted in accordance with Appendix B to 10 CFR Part 50.

This information notice requires no specific action or written response. If you have any questions about the information in 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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LIST OF RECENTLY ISSUED
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Information Notice No.	Subject	Date of Issuance	Issued to
2001-15	Non-Conservating Errors in Minimum Critical Power Ratio Limits	10/29/01	All holders of operating licenses or construction permits for boiling water reactors (BWRs)
2001-14	Problems with Incorrectly-Installed Swing-Check Valves	10/03/01	All holders of operating licenses or construction permits for nuclear power reactors except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel
2001-13	Inadequate Standby Liquid Control System Relief Valve Margin	08/10/01	All holders of operating licenses for boiling water reactors
2001-12 (ERRATA)	Hydrogen Fire at Nuclear Power Stations	8/08/01	All holders of operating licenses or construction permits for nuclear power reactors except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel
2001-12	Hydrogen Fire at Nuclear Power Stations	7/13/01	All holders of operating licenses or construction permits for nuclear power reactors except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel
2001-11	Thefts of Portable Gauges	07/13/01	All portable gauge licensees
2001-10	Failure of Central Sprinkler Company Model GB Series Fire Sprinkler Heads	06/28/01	All holders of licenses for nuclear power, research, and test reactors and fuel cycle facilities

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