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

April 7, 2005

NRC INFORMATION NOTICE 2005-09: INDICATIONS IN THERMALLY TREATED ALLOY 600 STEAM GENERATOR TUBES AND TUBE-TO-TUBESHEET WELDS

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 vessel.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to inform addressees about recent operating experience with degradation in steam generator tubes and tube-to-tubesheet welds. 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.

DESCRIPTION OF CIRCUMSTANCES

Catawba Nuclear Station, Unit 2, has four Westinghouse Model D5 recirculating steam generators. Each steam generator has approximately 4,600 tubes fabricated from thermally treated Alloy 600 (Figure 1). During fabrication of the steam generators, a portion of the U-shaped tubes are inserted into a thick plate called a tubesheet. The tubesheet is approximately 21 inches thick and has two holes for each tube (one hole on the hot-leg side of the steam generator and one hole on the cold-leg side). The lower end of the tubes were tack-expanded into the tubesheet for approximately 0.70 inch (Figure 2). This tack expansion is performed to facilitate welding of the tube to the primary side of the tubesheet. In the case of Catawba Unit 2, this region is frequently referred to as the tack roll region since the tack expansion was accomplished by mechanically rolling the tube into the tubesheet. The tack expansion forms a temporary expansion transition (i.e., a roll transition in the case of Catawba). Following welding, the tubes were hydraulically expanded for the full depth of the tubesheet. The transition from the expanded portion of tube within the tubesheet to the unexpanded portion of the tube at the top of the tubesheet is referred to as the expansion transition region of the tube.

In 2004, at Catawba Unit 2, Duke Energy (the licensee) conducted steam generator tube inspections. At the time of the inspections, Catawba Unit 2 had operated for approximately 14.7 effective full-power years and the licensee had never identified any cracklike indications in the steam generator tubes or welds.

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As part of the inspection, the licensee planned to use a rotating probe to inspect approximately 25 percent of the tubes in each of the steam generators from 2 inches above the top of the tubesheet to 9 inches below the top of the tubesheet. During the rotating probe examinations in the tubesheet region in steam generator B, the licensee found three discrete circumferential indications in an overexpanded region of one tube. Overexpanded regions such as this are sometimes called bulges or tubesheet anomalies. These terms are used to distinguish overexpanded regions of the tubes from regions that have been expanded above the top of the tubesheet, which may also be referred to as overexpansions. The indications were located approximately 7 inches below the top of the hot-leg tubesheet. The indications began from the inside diameter of the tubes and are approximately 30 degrees in circumferential extent. The overexpanded region extended for approximately 6 inches and the diameter was estimated to be approximately 0.003 inch greater than the diameter observed in the remainder of the expanded region. Overexpansions in the tubesheet region are a result of expanding the tube into a region of the tubesheet which is not perfectly round. This out-of-round condition is the result of anomalies introduced into the tubesheet during the drilling process (e.g., when the drill bit wanders). As a result of identifying these circumferential indications, the licensee increased the scope of the rotating probe examinations in the tubesheet region to include all tubes in all four steam generators with overexpanded regions in the hot leg. The licensee inspected these tubes from 2 inches above the top of the tubesheet to the tube end. A total of 1344 tubes in the hot-leg tubesheet region of all four steam generators have overexpanded regions.

During these additional rotating probe examinations, no additional indications were found in the overexpanded (bulged) regions; however, several indications were found at the tube ends (tube-to-tubesheet weld) and one indication was found in the tack expansion region. At the tube ends, the licensee identified approximately 12 indications in steam generators A, B, and D. These indications were in the tube-to-tubesheet weld and were not visible during visual inspections of the weld. The indication in the tack expansion (the region of the tube expanded into the tubesheet to facilitate welding) was approximately 0.70 inch above the tube-to-tubesheet weld and was circumferentially oriented. It was estimated to be 330 degrees in circumferential extent and 100 percent through-wall.

Based on these results, the licensee expanded the scope of the rotating probe examinations in the tack expansion region to include 100 percent of the tubes in steam generator B and 20 percent of the tubes in steam generators A, C, and D. These tubes were inspected from the tube end to approximately 2 inches above the tube end (which bounds the locations where the tube end indications were identified).

In steam generator B, 9 tubes were found to have indications in the tack roll region. These indications were circumferentially oriented and consisted of either single or multiple cracks. No indications were found in the tack roll region in steam generators A, C, or D. In the tube-to-tubesheet weld region, 188 tubes in steam generator B, 1 tube in steam generator A, and 7 tubes in steam generator D contained indications in the tube-to-tubesheet weld. No indications were found in the tube-to-tubesheet weld region in steam generator C. Six tubes in steam generator B were identified with tube end (i.e., tube-to-tubesheet weld) indications that extended into the tube material. The indications in these tubes were axially and circumferentially oriented and consisted of either single or multiple cracks.

The licensee plugged the tube with the circumferential indications in the overexpanded region and the tubes with indications in the tack roll region. In addition, the licensee plugged the six tubes with indications in the weld region that extended into the tube material.

BACKGROUND

In the U.S., only a few cracks (or cracklike indications) have been detected in steam generator tubes fabricated from thermally treated Alloy 600. Prior to 2004, most (if not all) of these indications occurred at two plants and were attributed to nonoptimal tube processing. These cracklike indications occurred in the region of the tube where it passes through the tube support plates. Additional information concerning this type of cracking is given in NRC Information Notice 2002-21, Supplement 1, “Axial Outside-Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing.”

DISCUSSION

The findings at Catawba Unit 2 are noteworthy because they indicate that degradation can potentially be occurring at various locations within the tubesheet region of thermally treated Alloy 600 tubes. The findings are also noteworthy because potential cracklike indications were first found in manufacturing anomalies (e.g., bulges or tubesheet anomalies) rather than at other tube locations such as the expansion transition or U-bend region. Historically, rotating probe inspections have focused on the expansion transition region on the hot-leg side and the U-bend region of tubes with short-bend radii. Inspections focused on these areas due to the high operating temperature and residual stress in these regions. The recent experience at Catawba shows the importance of monitoring all tube locations (such as bulges, dents, dings, and other anomalies from the manufacture of the steam generators) with techniques capable of finding potential forms of degradation that may be occurring at these locations (refer to Generic Letter 2004-001, “Requirements for Steam Generator Tube Inspections”). The Catawba experience also highlights the need to inspect all regions with high residual stress. Such inspections will provide added assurance that any degradation at these locations will be promptly detected.

The inspection of the tube-to-tubesheet weld and the repair of any indications detected in these welds are not governed by the surveillance requirements in the Catawba Unit 2 technical specifications. However, indications in the parent tube adjacent to the tube-to-tubesheet weld are governed by the plant technical specifications. Since the weld is designed at many plants to serve as part of the reactor coolant pressure boundary (i.e., it is a structural weld), the findings at Catawba illustrate the importance of inspecting the parent tube adjacent to the weld and the weld itself for degradation. Evaluating the results of these inspections is important for verifying the weld and the parent tube will continue to satisfy its design basis. Alternatively, redefining the reactor coolant pressure boundary using a different method of evaluation for the tube-to-tubesheet joint may demonstrate that degradation in this region is not safety significant.

Recent steam generator tube leaks at several plants with thermally treated Alloy 600 or Alloy 690 tubing (H.B. Robinson, Palo Verde, Shearon Harris) also show the need for thorough inspections and robust inservice inspection programs regardless of the tube material or steam generator history. Information Notices 2004-17, "Loose Part Detection and Computerized Eddy Current Data Analysis in Steam Generators," and 2004-16, "Tube Leakage Due to a Fabrication Flaw in a Replacement Steam Generator," provide additional details on some of these leakage events. Although corrosion-related degradation in plants with thermally treated tubing has been minimal, the recent operating experience at plants with thermally treated steam generator tubes indicates that damage by loose parts or damage incurred during manufacture of steam generator tubes can result in primary-to-secondary system leakage. This experience also shows the importance of being alert to all potential tube degradation mechanisms and to aggressively examine eddy current inspection signals that may be associated with tube degradation.

CONTACTS

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

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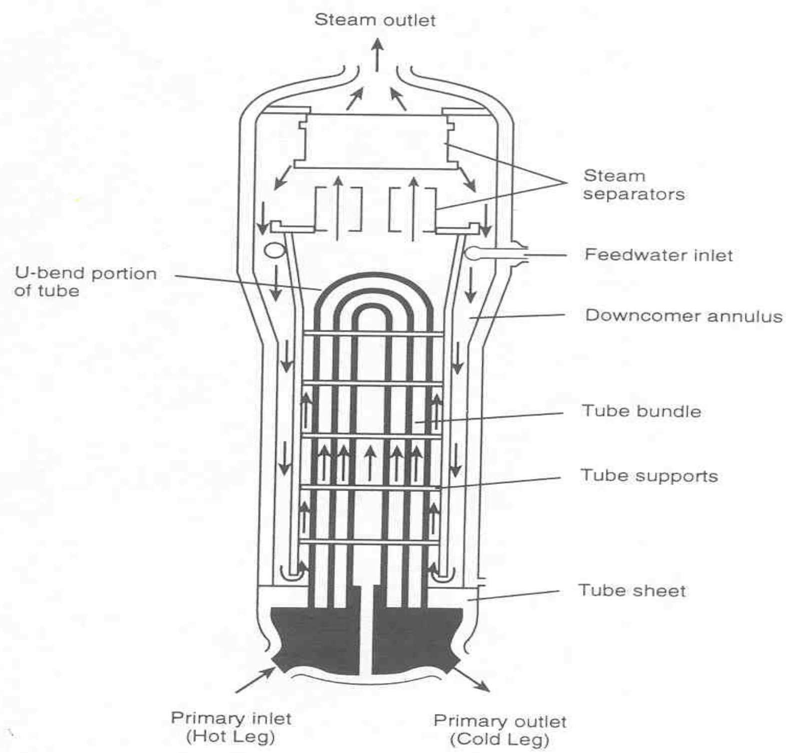
Attachments: 1. PWR Recirculating Steam Generator Figure 1
2. Tube Installed in the Tubesheet Figure 2

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



PWR Recirculating Steam Generator

Figure 1

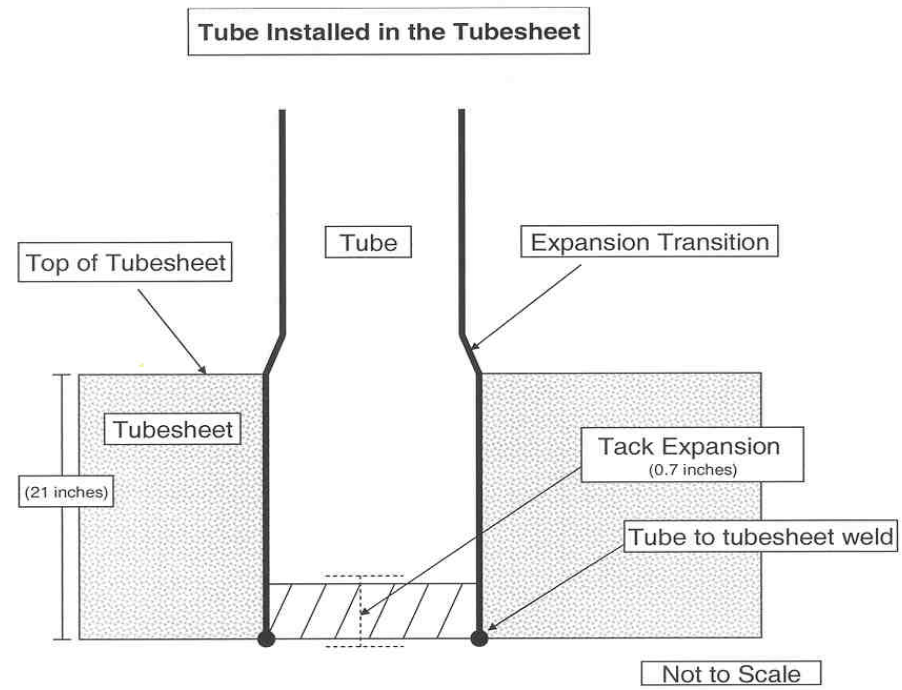

Tube Installed in the Tubesheet
Tube
Expansion Transition
Top of Tubesheet
Tubesheet
(21 inches)
Tack Expansion
(0.7 inches)
Tube to tubesheet weld
Not to Scale

Figure 2