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

April 24, 2008

NRC INFORMATION NOTICE 2008-07: CRACKING INDICATIONS IN THERMALLY TREATED ALLOY 600 STEAM GENERATOR TUBES

ADDRESSEES

All holders of operating licenses or construction permits for pressurized-water reactors except those that have permanently ceased operations and that 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 inform addressees of recent operating experience with degradation in steam generator tubes. 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

Recent operating experience has indicated the potential for cracking to occur in thermally treated Alloy 600 steam generator tubes at several nuclear stations, as described below.

Operating Experience at Vogtle Electric Generating Plant (Vogtle), Unit 1

Vogtle, Unit 1, has four Westinghouse Model F recirculating steam generators. Each steam generator has approximately 5600 tubes fabricated from thermally treated Alloy 600. During fabrication of the steam generators, the lower portions of the tubes were inserted and hydraulically expanded into a thick plate called a tubesheet. The tubesheet is approximately 533.4 mm (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 tubes were hydraulically expanded for the full depth of the tubesheet. The transition from the expanded portion of the 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. The tubes are welded to the tubesheet at their lower ends (See Enclosure, Figure 1).

In 2006, Southern Nuclear Operating Company (the licensee) conducted steam generator tube inspections at Vogtle, Unit 1. At the time of the inspections, Vogtle Unit 1 had operated for approximately 17.1 effective full-power years. The steam generators have operated at a hot-leg temperature of approximately 326 °C (618 °F) since commencement of plant operation.

As a result of +Point™ coil inspections on the hot-leg side of the steam generator from 76.2 mm (3 inches) above to 76.2 mm (3 inches) below the top of the tubesheet, the licensee identified 18 tubes that had indications attributed to outside-diameter stress-corrosion cracking. Of these 18 tubes, 17 tubes contained circumferentially oriented indications and 1 tube contained an axially oriented indication.

The circumferentially oriented indications were located at the bottom of the expansion transition at the top of the tubesheet on the hot-leg side of the steam generator. The axially oriented indication started in the expanded portion of the tube and stopped at the bottom of the expansion transition, i.e., most of the indication was in the expanded portion of the tube. The 18 indications were spread among the four steam generators, with most of the indications in steam generator 4. Most of the circumferential indications were located in tubes with low row numbers and high column numbers (i.e., in one of the "corners" of the steam generator). Most of the indications were confirmed to be present using several different eddy current inspection probes/coils including the Delta probe, the Ghent probe, the 2.032-mm (0.080-inch) diameter pancake coil, and the 2.921-mm (0.115-inch) diameter pancake coil. Some of the smaller amplitude signals were not identified with the 2.032-mm (0.080-inch) diameter pancake coil. The largest amplitude associated with the circumferential indications was 0.55 volts. The largest percent degraded area for the circumferential indications was estimated to be approximately 18 percent. The tube with the largest amplitude signal did not have the largest percent degraded area. All tubes with circumferential indications were stabilized. The axial indication was estimated to be 11.684 mm (0.46 inches) long and 68 percent through-wall using phase angle sizing and 92 percent through-wall using amplitude sizing. The amplitude associated with the axial indication was 1.77 volts.

The tubes with the circumferentially and axially oriented indications were removed from service by plugging both ends of the tubes. The licensee concluded that all of the tubes with these indications had adequate structural and leakage integrity.

Operating Experience at Catawba Nuclear Station (Catawba), Unit 2

Catawba, Unit 2, has four Westinghouse Model D5 recirculating steam generators. Each steam generator has 4570 tubes fabricated from thermally treated Alloy 600. The design of the tube-to-tubesheet joint is similar to that described above for Vogtle Unit 1.

In 2007, Duke Energy (the licensee) conducted steam generator tube inspections at Catawba, Unit 2. At the time of the inspections, Catawba Unit 2 had operated for approximately 17.4 effective full-power years. The steam generators have operated at a hot-leg temperature between 324 °C (615 °F) and 326 °C (618 °F) since the commencement of plant operation.

During the inspections, the licensee used an array probe to inspect the tubes. During these inspections, the licensee identified eight tubes with axially oriented indications. One of these tubes had multiple axial indications. All of the indications initiated from the outside surface of the tube on the hot-leg side of steam generator B. The indications were located slightly above the top of the tubesheet in the sludge pile (a region in the steam generator where deposits tend to accumulate). The array probe data from the tubesheet region were reviewed for all of the tubes in steam generator B. In the other three steam generators, the array probe data from the tubesheet region were reviewed for 20 percent of the tubes with no indications identified at the

top of the tubesheet. These eight tubes were removed from service by plugging both ends of the tubes. All of the tubes with these indications had adequate structural and leakage integrity.

In addition to the indications detected in the tubes near the top of the tubesheet, the licensee also detected indications near the tube end in both the hot leg and the cold leg. Indications near the tube end in the hot-leg side of the steam generator had been observed during prior inspections. There were 10 tubes identified with 15 circumferential indications on the cold-leg side of steam generators A and D. Nine of these 10 tubes were in steam generator D. These tubes were left in service since the licensee had been granted an amendment to the plant's technical specifications to leave tubes with flaws near the tube end in service.

Following the 2007 inspection outage at Catawba, Unit 2, eddy current analysts from several utilities and vendors reviewed the indications identified near the cold-leg tube end at Catawba, Unit 2. These analysts also reviewed data from a mockup of the tube-to-tubesheet joint that had axial and circumferential notches near the tube end with at least one circumferential notch in the tube-to-tubesheet weld. Based on this review, the consensus of the industry analysts was that the cold-leg tube end indications at Catawba, Unit 2 most likely exist in the tube; however, some of the indications extend close enough to the tube end that the possibility that the indications extend into the tube-to-tubesheet weld could not be ruled out.

BACKGROUND

Before 2006, crack-like indications had been detected in thermally treated Alloy 600 steam generator tubes at U.S. plants in the tubesheet region and at the tube support plate elevations. The crack-like indications in the tubesheet region initiated from the inside surface of the tubes and were either axially or circumferentially oriented. They were located in bulges within the tubesheet (circumferential) and near the tube end and possibly extending into the tube-to-tubesheet weld (axial and circumferential). Additional information concerning these types of indications appears in IN 2005-09, "Indications in Thermally Treated Alloy 600 Steam Generator Tubes and Tube-to-Tubesheet Welds," dated April 7, 2005. The crack-like indications at the tube support plate elevations were axially oriented, were initiated from the outside surface of the tube, and were associated with nonoptimal tube processing. Additional information concerning these types of indications appears in IN 2002-21, Supplement 1, "Axial Outside-Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing," dated April 1, 2003.

DISCUSSION

In the United States, 17 units have thermally treated Alloy 600. The steam generators at these units have been in service for approximately 20 years, on average. In 2002, the first incidence of corrosion-related cracking was reported in units with thermally treated Alloy 600. This cracking was attributed to nonoptimal tube processing (refer to IN 2002-21). Since then, a few other units with thermally treated Alloy 600 tube material have observed crack-like indications in their steam generators. These crack-like indications have occurred at several different locations.

Crack-like indications that initiate from the inside surface of the tube have been observed near the tube end and possibly extending into the tube-to-tubesheet weld and within bulges inside the tubesheet region. The crack-like indications within the bulges have only been observed on

the hot-leg side of the steam generators; however, the crack-like indications near the tube-end and possibly extending into the tube-to-tubesheet weld have been observed both on the hot-leg and cold-leg sides of the steam generators.

Crack-like indications that initiate from the outside surface of the tube have been observed in the expansion transition region, in the portion of tube slightly above the expansion transition, and at the tube support plate elevations (in tubes with nonoptimal tube processing). All of the indications that initiated from the outside surface of the tube near the top of the tubesheet were on the hot-leg side of the steam generator. The crack-like indications at the tube support plate elevations were observed both on the hot- and cold-leg side of the steam generator.

The number of tubes identified with corrosion-related cracking is small in comparison to the approximately 275,000 thermally treated Alloy 600 tubes in service. Although only a small number of tubes have been identified with crack-like indications, these findings indicate that the tubes are potentially susceptible to cracking at a variety of locations. In addition, the rate at which new cracks are found is expected to increase with time. These findings also illustrate the importance of carefully evaluating the potential for cracking to occur at other locations. The potential for cracking depends not only on the tube material, but also on the stresses in the tube and the operating environment (e.g., water chemistry, temperature). In some instances, it is difficult to quantify all of these parameters, making it important to have a conservative approach for inspecting tubes that are susceptible to corrosion-related degradation.

Technical specifications require the steam generator tubes to be inspected, and they require licensees to perform an assessment to determine the types and locations of flaws to which the tubes may be susceptible, as well as to determine which inspection methods need to be employed and at what locations. The objective is to detect flaws of any type that may satisfy the applicable tube repair criteria. Given the findings discussed above, additional locations along the length of the tube may need to be inspected for cracking.

CONTACT

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

/RA by TQuay for/

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Enclosure: "Tube Installed in the Tubesheet"

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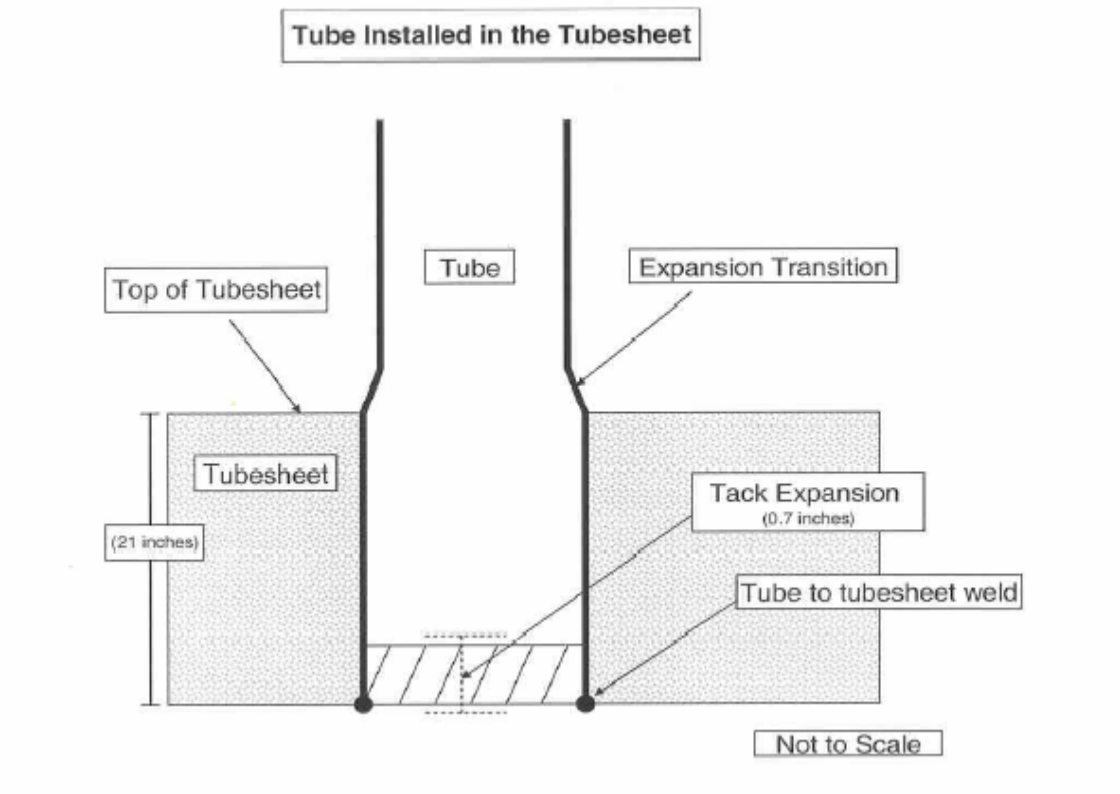
Tube Installed in the Tubesheet
Top of Tubesheet
Tube
Expansion Transition
Tubesheet
(21 inches)
Tack Expansion
(0.7 inches)
Tube to tubesheet weld
Not to Scale

Figure 1