UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
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NRC INFORMATION NOTICE 2005-29: STEAM GENERATOR TUBE AND SUPPORT CONFIGURATION

ADDRESSEES

All holders of operating licenses or construction permits 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 describe recent experience in which the configuration of steam generator tube supports or expansions was different than expected. 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

The following describes the as-found condition of the steam generators at Byron Unit 1, Davis-Besse, and Waterford Unit 3 during inspections performed during 2005.

Byron Unit 1

Byron Unit 1 replaced the four recirculating steam generators in 1997 with steam generators designed and fabricated by Babcock and Wilcox International. Each steam generator has 6,633 thermally treated Alloy 690 U-tubes. The U-tubes are supported by stainless steel lattice grid structures along the straight portion of the tube and by a collector bar and fan bars in the U-bend region. All fan bars are connected to the collector bar.

During the 2005 steam generator tube inspections, an evaluation of the bobbin coil eddy current data revealed that the collector bar did not completely engage all of the row 1 tubes in steam generator B as expected. Investigations discovered that the collector bar engaged, or partially engaged, only 10 of the 67 row 1 tubes on the hot-leg side of the steam generator, rather than engaging all 67 of the row 1 tubes. The collector bar was verified to engage all row 1 tubes on the cold-leg side of the steam generator. Additionally, the collector bar was verified to be engaged in all row 1 hot-leg and cold-leg tubes in the other three steam generators.

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The nonengaged collector bar of the row 1 hot-leg tubes was identified by eddy current data analysis software that was programmed to compare the existing support structure location with the design locations of the support structures (landmarks). Following identification of this condition, a review of past inspection data revealed that this condition existed before the replacement steam generators were placed into service. The licensee concluded that the condition was not the result of inservice degradation. Since the as-found condition of the steam generator was different than the condition analyzed during the design of the steam generator, an analysis was performed to show that the tubes remain adequately supported despite the mispositioning of the collector bar. Concerned that the "disengaged" tubes would vibrate and become worn at the lattice support or at the other collector bar location on the cold leg side, the licensee reviewed eddy current inspections at those locations and found no wear to date. The licensee concluded that flow-induced vibration is not increased due to the lack of contact with the collector bar.

Davis-Besse

Davis-Besse has two once-through steam generators designed and fabricated by Babcock and Wilcox International. Each steam generator contains approximately 15,500 Alloy 600 mill-annealed tubes. The tubes are partial-depth-expanded into both the upper and the lower tubesheet.

Based on recent operating experience at other similarly designed plants, a significant number of rotating probe inspections were performed at the tube end in the lower tubesheet (cold-leg) for the first time during the 2005 outage at Davis-Besse. While performing these inspections, most tubes (all but approximately 100 tubes) were identified as having two roll-expanded regions in the lower tubesheet. The presence of two rolls (rather than one) in the lower tubesheet region was not known by personnel responsible for determining potential forms of degradation that could affect the tubes. A review of fabrication records indicated the second roll was installed during the original manufacture of the steam generators since there was inadequate control of the original roll in the lower tubesheet and many of the original rolls were too short. The tubes were rerolled prior to annealing the steam generator. The second rolls are referred to as shop rerolls to distinguish them from reroll repairs performed subsequent to commercial operation. Approximately 30 tubes were plugged during the 2005 outage as a result of crack like indications detected at the shop rerolls in the lower tubesheet. None of the crack like indications were safety significant.

Waterford Unit 3

Waterford Unit 3 has two recirculating steam generators designed and fabricated by Combustion Engineering. The mill-annealed Alloy 600 steam generator tubes are supported in the straight portion of the tube by a number of carbon steel lattice grid (i.e., eggcrate) tube supports and in the U-bend region by diagonal bars (also called batwings) and vertical straps. Several of the lattice grid tube supports are referred to as partial eggcrate supports since they only support some of the tubes. The tubes in rows 1 through 18 are U-bends and the tubes in rows 19 through 147 are square bends (i.e., there are two 90-degree bends for tubes in rows 19 through 147).

Routine eddy current testing of the steam generator tubes in 2005 identified that two diagonal batwing supports in steam generator 2 had moved. The two batwings were displaced from their nominal locations on the cold-leg side of tubes in columns 82, 83, and 84. These batwings were at their nominal locations during the previous inspection. Wear scars were observed for tubes in these columns during the 2005 inspections. These wear scars occurred in the free span of the tube at the nominal axial location of the batwing and thus were apparently formed before the displacement of the batwings. These wear indications were not observed during the previous inspection. The depth of these wear indications ranged from 7- to 30-percent of the tube wall thickness.

The batwing assembly is formed by two opposing diagonal bars connected by a short horizontal bar. A visual inspection of the lower portion of the batwings confirmed that two batwings had failed at the intersection of the horizontal bar and a slotted bar, which runs perpendicularly to the horizontal bar and is keyed to the horizontal bar. The slotted bar holds the lower portion of the batwing in place. The licensee concluded that the failure mechanism was fatigue, based on the location of the failure, the length of the batwing (one of the longest in the steam generator), and the flow in this region of the tube bundle. The loads on the batwing in this region are not high enough to cause an overload-type failure.

As a result of these findings, several corrective actions were taken, including plugging and stabilizing many tubes, performing analyses, and evaluating the integrity of the batwing-to-wrapper bar welds. The analyses were done to confirm that tube integrity will not be compromised for the period of time between tube inspections if additional batwings fail. The evaluations were done to ensure that the failed batwings would not become free to move throughout the steam generator, (i.e., become loose parts). The batwing-to-wrapper bar welds connect all of the batwings and are located on the outside of the tube bundle to permit access for visual inspection.

BACKGROUND

High-cycle fatigue due to inadequate tube support (antivibration bar location anomalies) was the cause of a tube rupture in 1987 (Bulletin 88-02, “Rapidly Propagating Fatigue Cracks on Steam Generator Tubes”).

Steam generator internals can be important in ensuring that the tubes are capable of performing their intended safety function (Generic Letter 97-06, “Degradation of Steam Generator Internals”).

DISCUSSION

The positioning of the tube supports (e.g., antivibration bars, batwings, vertical straps, collector bars, fan bars, lattice grids, support plates) is important in ensuring the tubes are adequately supported. Inadequate tube support can result in increased tube vibration and increased tube wear and fatigue.

At Byron Unit 1, the nonengaged collector bar in the U-bend region of many row 1 tubes was discovered through a review of inspection data. The data indicated that the support was not in the correct position. This condition was identified by applying a computerized data-screening algorithm to the inspection data. In the case of Waterford 3, the failed batwing support was discovered by investigating several indications of wear that were apparently occurring at a location not associated with a support structure. In both cases, the actual tube support conditions were evaluated to identify any tube integrity concerns (e.g., flow-induced vibration). Prompt identification of supports that are not in their proper position (as a result of fabrication or from service-induced conditions) is important to ensure that appropriate actions are taken in a timely manner before tube integrity is compromised.

At Davis-Besse, the presence of a second roll expansion in the lower tubesheet was not known by responsible plant personnel. Roll expansions are locations of high stress and are more susceptible to degradation. As a result, it is important to know all locations of high stress to ensure that appropriate inspection techniques are used at those locations to detect possible degradation.

At Waterford Unit 3, additional evaluations and inspections were performed to ensure that the actual configuration of the failed batwings was stable. Since one end of each failed batwing was free to move, the welds securing the other ends were evaluated to ensure the failed batwings would not become free during operation and potentially impact other tubes. Evaluating the as-found condition to ensure that continued degradation will not result in the generation of loose parts is also important for ensuring tube integrity.

In summary, it is important to compare the as-found condition of the steam generator to the steam generator design. This includes confirming that the as-found location of the steam generator tube supports is consistent with the original design. Significant differences between the as-found and as-designed location of the tube supports can result in increased tube vibration and increased tube wear and fatigue. Promptly identifying significant differences between the as-found and as-designed configuration may prevent a loss of tube integrity. Similarly, monitoring the current condition and location of the tube supports is important to ensure that any service-induced degradation or movement of the supports is promptly detected and evaluated. In addition, it is important to know the actual configuration of the steam generator tubes to ensure that all high-stress locations are identified in the degradation assessment and inspected with techniques capable of detecting the forms of degradation that may occur at those locations.

CONTACT

Please direct any questions about this matter to the technical contact(s) or the Lead Project Manager listed below, or to the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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