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January 7, 2014

Mr. Michael J. Pacilio
Senior Vice President
Exelon Generation Company, LLC
President and Chief Nuclear Officer
Exelon Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: BRAIDWOOD STATION, UNIT 2 – REVIEW OF THE 2012 STEAM GENERATOR TUBE INSERVICE INSPECTIONS (TAC NO. MF0659)

Dear Mr. Pacilio:

On October 24, 2012, the staff of the Steam Generator Tube Integrity and Chemical Engineering Branch (ESGB) of the Division of Engineering participated in a conference call with representatives of Exelon regarding its steam generator (SG) tube inspection activities at Braidwood Station, Unit 2. Enclosed is a summary of the conference call.

By letters dated February 5, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13039A042), and August 6, 2013 (ADAMS Accession No. ML13219A320), Exelon Generation Company, LLC (the licensee) submitted information summarizing the results of the 2012 SG tube inspections at Braidwood Station, Unit 2. These inspections were performed during the 16th refueling outage.

The staff concludes that the licensee provided the information required by their technical specification and did not identify any technical issues that warrant follow-up action at this time.

The staff's review of the report and a summary of the related October 24, 2012, conference call with Exelon are enclosed.

Sincerely,

Joel S. Wiebe, Senior Project Manager
Plant Licensing Branch III-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-457

Enclosure:
Review of the 2012 Steam Generator Tube Inservice Inspections

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REVIEW OF THE 2012 STEAM GENERATOR TUBE INSERVICE INSPECTIONS

BRAIDWOOD STATION, UNIT 2

DOCKET NO. 50-457

Conference Call During the 16th Refueling Outage (RFO16)

On October 24, 2012, the staff of the Steam Generator Tube Integrity and Chemical Engineering Branch of the Division of Engineering participated in a conference call with representatives of Exelon Generation Company, LLC (the licensee) regarding their ongoing steam generator (SG) tube inspection activities at Braidwood Station, Unit 2.

Braidwood Station, Unit 2, has four Westinghouse Model D5 SGs, each containing 4,570 thermally treated Alloy 600 tubes. The tubes have a nominal outside diameter of 0.750 inches and a nominal wall thickness of 0.043 inches. The tubes were hydraulically expanded at both ends for the full length of the tubesheet and are supported by a number of stainless steel tube supports with quatrefoil-shaped holes. The U-bend region of the tubes in rows 1 through 9 was thermally stress relieved after bending.

Information provided by the licensee during the phone call is summarized below.

The SGs have been in service for 21.27 effective full-power years and the current inspection is at the midpoint of the first 60 effective full-power month (EFPM) sequential inspection period. At the start of the outage, 259 tubes had been plugged in the Braidwood Station, Unit 2, SGs.

There was no primary-to-secondary leakage in the cycle preceding the A2R16 (fall 2012) inspection.

At the time of the conference call, the inspections were approximately 91.4 percent complete. The following primary side inspections were scheduled to be performed:

- 100 percent of tubes in all four SGs with a bobbin probe
- 25 percent of the tubes on the hot-leg side of the SG from four inches above the top of the tubesheet (TTS) to 14.01 inches below the TTS with a +Point probe
- The U-bend region of 25 percent of the tubes in rows 1 and 2 with a +Point probe
- 25 percent of the hot-leg tubes with dents and dings that were greater than 3.0 volts (as determined from the bobbin coil) with a +Point probe
- 25 percent of the pre-heater baffle plate expansions with a +Point probe

Enclosure

Sludge lancing and visual inspections of the top of the tubesheet were scheduled to be performed in all four SGs. In addition, visual inspections were scheduled to be performed in the pre-heater region in SGs B and C. Furthermore, visual inspections were scheduled to be performed in the upper tube bundle in SG C at the 8$^{th}$ and 11$^{th}$ tube support plates.

At the time of the conference call, wear was detected at the anti-vibration bars (largest indication was 40 percent through-wall), at the pre-heater tube supports (largest was 15 percent through-wall), and near foreign objects/loose parts (largest was 39 percent through-wall). In addition, three axially oriented indications were found on the hot-leg side of the tube in row 44, column 47, in SG C. In SG B, foreign object wear at the 7H tube support plate was identified. Since no visual inspections of this region were performed, the affected tubes are being stabilized and plugged.

At the time of the call, sludge lancing was complete in SGs A, B, and C, and had not been completed in SG D. Sludge lancing had resulted in removal of 41, 47.5, and 57.5 pounds of sludge from SGs A, B, and C, respectively.

The SG post sludge lancing top of tubesheet foreign object search and retrieval (FOSAR) was scheduled to be performed in all four SGs. At the time of the call, the top of tubesheet FOSAR was on-going in SG A, complete in SG B (two objects were identified including one object that had been observed in the past which is lodged in place, and one wire which was removed), and complete in SG C (no objects identified). FOSAR had not commenced in SG D at the time of the call.

As a result of the visual inspections of the pre-heater regions in SG B, 32 foreign objects were identified including 29 wire bristles (five of which had been observed in the past but were not removed), two historical objects (not removed), and one machine turning. Twenty one of these 32 foreign objects were not removed from the SG.

As a result of the visual inspections of the pre-heater regions in SG C, 18 foreign objects were identified. All but six of these foreign objects were removed from the SG.

Several of the foreign objects identified during the visual inspections were bright red in nature. No samples of this material could be obtained.

Another utility with thermally treated Alloy 600 tubing had detected three free span indications attributed axially oriented outside diameter stress corrosion cracking. This utility also detected axially oriented outside diameter stress corrosion cracking at a dented tube support plate. As a result of this operating experience, representatives from Braidwood 2 confirmed their automatic data analysis system would identify these types of flaws. In addition, they trained their eddy current data analysts to identify these types of indications.

During the 2012, inspections, there was one tube (row 44, column 47, in SG C) at Braidwood Station, Unit 2, in which three axially oriented indications, representative of outside diameter stress corrosion cracking, were identified. Two of these indications were at the support plate elevations (3H and 5H) and one was in the free span region of the tube between the 3H and 5H tube support plate (approximately 34-inches above the 3H tube support). The indications were not aligned axially along the length of the tube (as evidenced from the +Point data which was acquired from 3-inches above the 5H support plate to 3-inches below the 3H support plate). In

addition, there was no evidence of a scratch along the length of the tube. The indication at the 3H tube support plate met the criteria for performing an in-situ pressure test (i.e., it exceeded the structurally equivalent length and average depth criteria).

The three indications at Braidwood Station, Unit 2, were sized with a +Point probe using an Electric Power Research Institute, Appendix I, technique (28342). The indication at 3H measured 0.64 volts and was 0.56-inches long and had a maximum depth of 69.6 percent through-wall. The indication at 5H measured 0.25 volts and was 0.48-inches long and had a maximum depth of 50 percent through-wall. The freespan indication measured 0.39 volts and was 0.19-inches long and had a maximum depth of 56.4 percent through-wall. The freespan indication was located at a low level ding location. An inspection of these indications with a ghent probe confirmed the results obtained with the +Point probe.

The indication at 3H successfully passed the in-situ pressure test with no leakage being observed at any test pressure (including the test pressure associated with three times the normal operating differential pressure). The test pressures were adjusted to account for the difference in material properties at normal operating conditions and at room temperature (since the in-situ test was performed at room temperature). The test pressure was increased in approximately 500 pounds per square inch increments until the final test pressure was reached. A full tube pressure test was not performed (which would have tested all three indications) since only the indication at the 3H support plate exceeded the in-situ pressure test screening criteria.

During the production analysis, only the indication at the 3H tube support plate was identified. The other two indications in this tube (at 5H and in the freespan) were identified by the independent qualified data analyst. The primary analysis (of the bobbin coil data) was performed using an automated data analysis system operated in the interactive mode and the secondary analysis was performed manually by human analysts. An investigation into why the freespan indication was not identified by the automated analysis system revealed that the freespan indication had a phase angle of 151 degrees whereas the sort was established to only identify indications that were less than 150 degrees. As a result of these findings, the licensee increased their criterion to 151 degrees. The NRC staff questioned the basis for this criterion particularly with respect to operating experience at other utilities even those with mill annealed Alloy 600 tubing. The licensee indicated that this criterion would identify the missed indication and that increasing the criteria any more would result in identifying many more indications (which was most likely non-flaw like). The NRC staff asked, and the licensee agreed, to notify the staff if any more indications were identified as a result of increasing the phase angle criterion to 151 degrees.

The licensee also investigated why the indication at the 5H tube support plate was missed by the automated data analysis system. The licensee indicated that in order for the analysis logic to be applied at a tube support plate, the entire tube support plate had to be in a window size of 27. Since the entire 5H tube support plate was not within this window size, the automated system did not apply the flaw identification algorithm at this location. By increasing the window size to 31, which the licensee did, the licensee indicated that all tube support plates would have the flaw identification algorithm applied. As a result, similar indications would be identified at other tube support plates. The licensee also reduced the voltage threshold for identifying the tube support plate region from 1 volt to 0.8 volts.

At the time of the conference call, the licensee was re-screening the bobbin coil data with the automated data analysis system operated in the interactive mode with these revised criteria. For all indications identified as a result of increasing the window size to 151 degrees, the licensee planned to perform a review of the prior eddy current data to determine if there was any change. If there was any change, the indications would be inspected with a rotating probe.

An investigation into why the human analysts missed the indications was on-going at the time of the conference call.

A review of the prior inspection data for the three indications attributed to outside diameter stress corrosion cracking was performed. This review indicated that there was a 20 degree change in the phase angle of the freespan indication (which appeared ding-like) from 1990 to the present. For the indications at the tube supports, there were no indications present in the 2009 data at either support and there was no indication present in the 2011 data for the 5H tube support plate; however, with hindsight, some evidence of a signal could be seen in the 2011 data for the signal at the 3H tube support plate (but the signal would not have been reportable).

The staff did not identify any issues that required immediate follow-up action; however, the staff asked to be notified in the event that any unusual conditions were detected during the remainder of the outage or if additional crack-like indications were identified.

Subsequent to the call, the NRC staff was notified that approximately 10 additional tubes were identified as requiring inspection with a rotating probe as a result of the additional eddy current screening. No additional flaws were identified during these inspections. In addition, the NRC staff was notified that the tube with the axially oriented indications attributed to outside diameter stress corrosion cracking should have been identified as a "2-sigma tube", with potentially elevated residual stresses since the tube had no U-bend offset signal. Two previously identified 2-sigma tubes were also determined to have no U-bend offset signal when compared to the straight portions of the tubes. Therefore, the previously identified 2-sigma tubes with no U-bend offset were preventatively plugged. The tube with the axially oriented indications was also plugged. Approximately 11 tubes will be plugged during this outage.

Review of the RFO16 SG Inspection Summary

By letters dated February 5, 2013 (ADAMS Accession No. ML13039A042), and August 6, 2013 (ADAMS Accession No. ML13219A320), Exelon Generation Company, LLC (the licensee) submitted information summarizing the results of the 2012 SG tube inspections at Braidwood Station, Unit 2. These inspections were performed during RFO16. The licensee also provided some clarifying information concerning the 2012 inspections in a phone call on October 23, 2013. The details of these clarifications are summarized below.

Braidwood Station, Unit 2, has four Westinghouse Model D5 SGs. There are 4570 thermally treated Alloy 600 tubes in each SG, with an outside diameter of 0.750 inches, and a nominal wall thickness of 0.043 inches. The tubes are hydraulically expanded for the full depth of the tubesheet at each end and are welded to the tubesheet at the bottom of each expansion. The tubes are supported by a number of Type 405 stainless steel supports with quatrefoil shaped holes.

At the time of this inspection (i.e., RFO16), the SGs had accumulated 241.06 EFPMs of operation since the first inservice inspection (i.e., RFO1), and were at the midpoint of the first 60 EFPM inspection period.

The licensee provided the scope, extent, methods, and results of their SG tube inspections in the documents referenced above. In addition, the licensee described corrective actions, such as tube plugging, taken in response to the inspection findings. The tubes in all four SGs were inspected during this refueling outage.

After reviewing the information provided by the licensee, the staff has the following comments/observations:

- The modes of tube degradation found during RFO16 were anti-vibration bar wear, pre-heater tube support plate wear, secondary side foreign object wear, and axial outside diameter stress corrosion cracking.

- The licensee performed visual inspections of the upper tube bundle at the 8th and 11$^{th}$ tube support plates (TSPs) on both the hot-leg and cold-leg sides of SG C. In general, the quatrefoil holes of the TSPs were free of blockage on the cold-leg side, and only contained trace amounts of scale. The amount of blockage on the hot-leg side was visually estimated to be approximately 10 percent or less; however, the majority of the flow holes did not exhibit scale formation or blockage. Overall, deposit blockage appears to have affected more quatrefoil flow holes in RFO16 than it did in RFO14.

- During the secondary side visual inspections, a red substance was identified at 20 locations. This substance could not be retrieved or sampled.

- One tube in SG C was plugged for three indications of axial outside diameter stress corrosion cracking. The third and fifth hot-leg TSPs each contained one indication at a single quatrefoil land. Additionally, one indication that originated from a low-level ding (i.e., 1.0 volt) indication was found in the freespan between the third and fifth TSP. Additional information concerning these indications is contained in Information Notice 2013-11, "Crack-Like Indications at Dents/Dings and in the Freespan Region of Thermally Treated Alloy 600 Steam Generator Tubes" (ADAMS Accession No. ML13127A236).

In the October 23, 2013, phone call, the licensee clarified the following:

- That the bobbin probe is not the only probe that is necessary to meet the 50-percent mid-point technical specification inspection requirement.

- That their sampling inspection program is done "without replacement" to ensure that there are no redundant tube inspections (i.e., two 25-percent samples result in 50-percent of the tubes being inspected). In some cases, additional special interest tubes, which may have been inspected in a 25-percent sample in a prior outage, may be inspected again, but these inspections are in addition to the 25-percent "without replacement" inspections.

Based on a review of the information provided by the licensee, the staff concludes that the licensee provided the information required by their technical specifications. The SG tube inspections at Braidwood, Unit 2, appear to be consistent with the objective of detecting potential tube degradation and the inspection results appear to be consistent with industry operating experience at similarly designed and operated units.

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