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NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
OFFICE OF NEW REACTORS
WASHINGTON, DC 20555-0001

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NRC INFORMATION NOTICE 2013-11: CRACK-LIKE INDICATIONS AT DENTS/DINGS AND IN THE FREESPAN REGION OF THERMALLY TREATED ALLOY 600 STEAM GENERATOR TUBES

ADDRESSEES

All holders of an operating license or construction permit for a nuclear power reactor under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those that have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of and applicants for a power reactor early site permit, combined license, standard design certification, standard design approval, or manufacturing license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of the detection of crack-like indications at dented/dinged locations and in the freespan region in thermally treated Alloy 600 steam generator tubes. The NRC expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to ensure they meet regulatory requirements. Suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

As discussed below, indications of cracking at dents/dings and in the freespan region were discovered in thermally treated Alloy 600 steam generator tubes.

<u>Seabrook Station, Unit 1</u>

Seabrook Station, Unit 1 (Seabrook), has four recirculating steam generators, each of which has approximately 5,600 tubes fabricated from thermally treated Alloy 600. The tubes are supported in the straight region by a flow distribution baffle and several tube support plates, and in the U-bend region by anti-vibration bars.

In fall 2012, NextEra Energy Seabrook, LLC (the licensee), conducted steam generator tube inspections at Seabrook. All tubes were inspected full length with a bobbin coil probe, except for the U-bend region of the tubes in rows 1 and 2. Various locations of the tube, including the U-bend region of some of the row 1 and 2 tubes, were inspected using a rotating probe equipped with a +Point™ coil. At the time of the inspections, Seabrook had operated approximately 18.95 effective full-power years. The steam generators had operated at a hot-leg

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temperature of approximately 325.6 degrees Celsius (618 degrees Fahrenheit) since commencement of commercial operation until implementation of a power uprate in 2005. Thereafter, the steam generators had operated at 327 degrees Celsius (621 degrees Fahrenheit).

During the bobbin coil inspections, the licensee detected an indication in the freespan region of a tube on the hot-leg side of the steam generator between the flow distribution baffle and the first tube support plate. The licensee used a rotating probe equipped with a +Point™ coil to further inspect the region where the bobbin coil indication was detected and confirmed that the indication was axially oriented, crack-like, and had initiated from the outside diameter of the tube (outside diameter stress corrosion cracking (ODSCC)). The indication had a +Point™ voltage amplitude of approximately 0.96 volts, a length of 0.52 inches, and a maximum depth of 77 percent of the tube wall thickness.

The rotating probe inspections also identified two additional ODSCC indications, which were not detected during the bobbin coil inspections. These additional indications were approximately 6 inches above the initially detected indication and were smaller in size. One indication had a +Point™ voltage of 0.24 volts, a length of 0.3 centimeters (0.15 inches), and a maximum depth of 45 percent of the tube wall thickness. The other indication had a +Point™ voltage amplitude of 0.38 volts, a length of 0.46 centimeters (0.18 inches), and a maximum depth of 56 percent of the tube wall thickness.

Although there was no reportable bobbin signal at these two additional locations, there were benign signals at these locations since the preservice inspection. These benign signals were characterized as small dents/dings from the preservice inspection data and had exhibited local conductivity changes after the first cycle of operation at temperature. The licensee concluded that the three indications are not components of a single indication since the indications are separated by ligaments of sound material and are not in the same axial plane.

In addition to these three indications of axially oriented ODSCC in one tube, another axially oriented ODSCC indication was detected in another tube. This latter indication was associated with a dented/dinged region of the tube at the top tube support plate on the hot-leg side of the steam generator. There were two dents/dings in this tube at the uppermost tube support plate: one at the bottom edge of the tube support plate had a bobbin voltage amplitude of 11.35 volts, and one at the upper edge of the tube support plate had a bobbin voltage amplitude of 8.96 volts. The crack-like indication was associated with the dent/ding at the lower edge of the tube support plate and was detected during the rotating probe inspections of dents/dings. A rotating probe is typically used to inspect dents/dings that have bobbin voltage amplitudes greater than 5 volts since the bobbin coil is not qualified to detect crack-like indications in such dents/dings.

The crack-like indication had a +Point™ coil voltage amplitude of 0.89 volts, a length of 0.56 centimeters (0.22 inches), and a maximum depth of 76 percent of the tube wall thickness. Since the original scope of inspections only included a 50 percent sample of the hot-leg and U-bend dents/dings that had bobbin voltage amplitudes greater than 5 volts, the inspection scope in the steam generator in which the crack-like indication was detected was expanded to include: 100 percent of the hot-leg and U-bend dents/dings, with bobbin voltage amplitudes greater than 5 volts, 100 percent of the cold-leg dents/dings with bobbin voltage amplitudes greater than 5 volts at the uppermost support plate, a 20 percent sample of the hot-leg and U-bend dents/dings that had bobbin voltage amplitudes greater than 2 volts and less than or equal to 5 volts, and a 20 percent sample of the dents/dings that had bobbin voltage amplitudes greater than 2 volts and less than or equal to 5 volts at the uppermost cold-leg tube support plate. The scope of the inspections in the other three steam generators was not expanded. No additional crack-like indications associated with dents/dings were detected in any of the four steam generators during the inspection.

The tubes with the axially oriented ODSCC were removed from service by plugging both ends of the tubes. Both of the tubes with these indications had adequate structural and leakage integrity. Neither of the tubes had any evidence of high residual stress as a result of non-optimal tube processing as discussed in NRC IN 2002-21, Supplement 1, “Axial Outside-Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing.”

Additional information is available in “Seabrook Station—Steam Generator Tube Inspection Report,” dated December 31, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13008A160).

Braidwood Station, Unit 2

Braidwood Station, Unit 2 (Braidwood Unit 2), has four recirculating steam generators, each of which has 4,570 tubes fabricated from thermally treated Alloy 600.

In the fall of 2012, Exelon Generation Company, LLC (the licensee), conducted steam generator tube inspections at Braidwood Unit 2. All tubes were inspected full length with a bobbin coil probe, except for the U-bend region of the tubes in rows 1 and 2. The licensee inspected various locations of the tube using a rotating probe equipped with a +Point™ coil. At the time of the inspections, Braidwood Unit 2 had operated approximately 21.3 effective full-power years. The steam generators have generally operated at a hot-leg temperature of approximately 322 degrees Celsius (611 degrees Fahrenheit).

As a result of the operating experience at Seabrook described above, the licensee for Braidwood Unit 2 confirmed that its automatic eddy current data analysis system would identify the types of flaws observed at Seabrook. In addition, the licensee trained its eddy current data analysts to identify these types of indications.

During the 2012 inspections, one tube at Braidwood, Unit 2, was identified to have three axially oriented indications that were attributed to ODSCC. Two of these indications were located at tube support plate elevations (at the 3H and 5H tube support plate) and one was in the freespan region of the tube between the 3H and 5H tube support plate elevations (approximately 86 centimeters (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 8 centimeters (3 inches) below the 3H support plate to 8 centimeters (3 inches) above the 5H support plate.

The indication at 3H had a +Point™ voltage amplitude of 0.64 volts, a length of 1.4 centimeters (0.56 inches), and a maximum depth of 69.6 percent of the tube wall thickness. The indication at 5H had a +Point™ voltage amplitude of 0.25 volts, a length of 1.2 centimeters (0.48 inches), and a maximum depth of 50 percent of the tube wall thickness. The freespan indication had a +Point™ voltage amplitude of 0.34 volts, a length of 0.48 centimeters (0.19 inches), and a maximum depth of 56.4 percent of the tube wall thickness. There was no evidence of a scratch along the length of the tube. The freespan indication was associated with a ding with a bobbin voltage amplitude of approximately 1 volt. The affected tube was identified as potentially having elevated residual stresses caused by non-optimal tube processing since the tube had no

U-bend offset signal (typically referred to as a “2-sigma tube”). This tube was removed from service by plugging both ends of the tube.

The indication at the 3H tube support plate was in-situ pressure tested, with no leakage observed at any test pressure, including the test pressure associated with three times the normal operating differential pressure. Only the indication at 3H was tested since it exceeded the threshold for performing in-situ pressure testing.

During the original production analysis of the bobbin coil eddy current data, 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 not identified by either the primary or secondary analysis of the data, but rather 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 using 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 flaw identification algorithm was set to only identify indications that were less than 150 degrees. As a result of these findings, the licensee increased its criterion to 151 degrees. The criterion was not increased above 151 degrees because of concerns that many nonflaw-like signals would be identified.

The automated data analysis system missed the indication at the 5H tube support plate because the flaw identification algorithm was not applied at this location. In order for the automated flaw identification algorithm to apply at a tube support plate, the entire tube support plate must be contained within a data evaluation 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. The licensee increased the window size to 31 to ensure the flaw identification algorithm would be applied to all tube support plates. The licensee also reduced the voltage threshold for identifying the tube support plate region from 1 volt to 0.8 volts.

As a result of these findings, all bobbin coil data was re-analyzed with the automated data analysis system operated in the interactive mode with the revised criteria. The re-analysis identified no additional crack-like indications.

The licensee reviewed the prior inspection data for the three indications attributed to ODSCC. 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).

Additional information is available in “Braidwood Station, Unit 2 Steam Generator Tube Inspection Report for Refueling Outage 16,” dated February 5, 2013 (ADAMS Accession No. ML13039A042).

BACKGROUND

Related NRC Generic Communications

NRC IN 2010-21, "Crack-Like Indication in the U-bend Region of a Thermally Treated Alloy 600 Steam Generator Tube," dated October 6, 2010 (ADAMS Accession No. ML102210244). This IN alerted addressees to the detection of a crack-like indication in the U-bend region of a thermally treated Alloy 600 steam generator tube.

NRC IN 2010-05, "Management of Steam Generator Loose Parts and Automated Eddy Current Data Analysis," dated February 3, 2010 (ADAMS Accession No. ML093640691). This IN alerted addressees to loose parts (foreign objects) in steam generators and the use of automatic steam generator eddy current data analysis systems.

NRC IN 2008-07, "Cracking Indications in Thermally Treated Alloy 600 Steam Generator Tubes," dated April 24, 2008 (ADAMS Accession No. ML080040353). This IN alerted addressees to degradation in steam generator tubes.

NRC IN 2005-09, "Indications in Thermally Treated Alloy 600 Steam Generator Tubes and Tube-to-Tubesheet Welds," dated April 7, 2005 (ADAMS Accession No. ML050530400). This IN alerted addressees to degradation in steam generator tubes and tube-to-tubesheet welds.

NRC IN 2004-17, "Loose Part Detection and Computerized Eddy Current Data Analysis in Steam Generators," dated August 25, 2004 (ADAMS Accession No. ML042180094). This IN alerted addressees to (1) challenges associated with detection of loose parts and related tube damage in steam generators, and (2) computerized data screening algorithms used in the evaluation of steam generator tube eddy current data.

NRC IN 2002-21, Supplement 1, "Axial Outside-Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing," dated April 1, 2003 (ADAMS Accession No. ML030900517). This IN alerted addressees to the root cause assessment for the axially oriented outside-diameter crack indications in the thermally treated Alloy 600 steam generator tubing at Seabrook.

NRC IN 2002-21, "Axial Outside Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing," dated June 25, 2002 (ADAMS Accession No. ML021770094). This IN alerted addressees to preliminary indications of axial outside-diameter cracking of thermally treated Alloy 600 steam generator tubing at Seabrook.

DISCUSSION

There are 17 units in the United States with thermally treated Alloy 600 steam generator tubes. The steam generators at these units have been in service, on average, for approximately 25 calendar years. In 2002, the first incidence of corrosion-related cracking was reported in units with thermally treated Alloy 600 steam generator tubing. This cracking was attributed to non-optimal tube processing (refer to NRC IN 2002-21). Since then, several other units with thermally treated Alloy 600 tube material observed crack-like indications in their steam generators. These crack-like indications occurred in the United States at several different locations along the length of the tube, including in the tubesheet region, at the top of the tubesheet, at tube support plate elevations, and in the U-bend. 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.

The recent instances of cracking at Seabrook and Braidwood, Unit 2, are the first reported instances of cracking in the freespan region of the tube and at dented/dinged regions in units with thermally treated Alloy 600 tubing. The crack-like indications not initially detected with the bobbin coil at Seabrook and Braidwood Unit 2 illustrate the challenges in identifying crack-like indications and the need to be diligent in reviewing inspection data. The role the small dings played in initiating the freespan crack-like indications, if any, is not known since the tubes were not removed for destructive examination.

As discussed below, the finding of the one crack-like indication at a dented/dinged location at Seabrook potentially illustrates two other limitations related to (1) relying on the temperature dependence of cracking to focus inspections and (2) using a sampling strategy when the number of flaws that potentially exist is low.

Stress corrosion cracking is a temperature-dependent phenomenon and typically results in cracks being more prevalent at units operating at higher temperatures and finding a larger number of cracks in hotter regions of the tube. Assuming dents/dings with similar severities are located in hotter regions of the tube at Seabrook (i.e., at lower locations on the hot-leg side of the tube), the finding of a crack-like indication at the uppermost hot-leg tube support plate, rather than at one of these postulated dents/dings in the hotter regions of the tube, indicates a potential weakness of a sampling strategy that focuses the dent/ding inspections at the hotter tube locations. This is because the potential for cracking depends not only on the temperature, but also on the tube material, the stresses in the tube, and other operating parameters (e.g., water chemistry). In some instances, it is difficult to quantify all of these parameters such that a simple sampling strategy can be developed.

Given the relatively low number of crack-like indications being found in units with thermally treated Alloy 600 tubing (e.g., one crack-like indication in a dent/ding), a sampling strategy in lieu of inspecting all susceptible locations may result in missing crack-like indications.

The operating experience described above illustrates the importance of inspecting locations susceptible to degradation with probes capable of detecting that degradation and the challenges and limitations of implementing a sampling strategy (e.g., based solely on the temperature dependence of cracking or when only a limited number of flaws may be present in a steam generator). In addition, the operating experience indicates that crack-like indications may be missed during inspections. These items should be considered in establishing the appropriate operating interval between inspections.

The findings at Braidwood Unit 2, regarding the initial setup of the computerized data analysis system indicate the importance of properly establishing the parameters for computerized data analysis algorithms. A rigorous technical basis should exist for these parameters to provide assurance that the inspections are performed with the objective of detecting flaws that may satisfy the applicable tube plugging or repair criteria.

CONTACT

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below or to the appropriate NRC project manager.

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Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under the NRC Library

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