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

July 17, 2012

NRC INFORMATION NOTICE 2012-07: TUBE-TO-TUBE CONTACT RESULTING IN WEAR IN ONCE-THROUGH STEAM GENERATORS

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 who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of or applicants for an early site permit, standard design certification, standard design approval, manufacturing license, or combined 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 wear indications as a result of tube-to-tube contact in once-through steam generators and the lessons learned from the discovery of these indications. These lessons learned apply to all steam generator types since they address detection of tube degradation. It should be noted that as this IN was being written and issued, there is an on-going assessment of wear attributed to tube-to-tube contact that occurred at San Onofre Nuclear Generating Station, which uses recirculating steam generators. The NRC expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. Suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

Three Mile Island, Unit 1 (TMI-1), completed the replacement of both of its original once-through steam generators in early 2010, after exiting a refueling outage that began in the fall of 2009. AREVA (France) fabricated the replacement steam generators. The tubes in the steam generator are straight and supported by 15 tube support plates. The center of the tubes is located approximately 15 centimeters (6 inches) below the eighth tube support plate (between the seventh and eighth tube support plates).

The first inservice inspection of the TMI-1 replacement steam generators took place in fall 2011. During this inspection, the TMI-1 licensee inspected 100-percent of the tubes in both steam generators with a bobbin coil probe, which is an eddy current nondestructive examination technique. The bobbin coil probe is operated in both an absolute and differential mode. In the differential mode, the probe is sensitive to localized variations along the length of the tube, such as cracks or pits. However, this mode is not sensitive to gradual variations along the length of

the tubing. In the absolute mode, the probe is sensitive to long and gradual changes along the length of the tubing.

During these inspections at TMI-1, the licensee detected several tubes with indications on the absolute channel with no discernable signal being observed on the differential channel. A comprehensive review of all of the absolute drift indications revealed that most of them were near the middle of the tube's total length (between the eighth and ninth tube support plate), were in a radial pattern approximately 76 centimeters to 114 centimeters (30 inches to 45 inches) from the center of the steam generator, and in adjacent tubes (two or three). In addition, the indications in adjacent tubes faced each other, were at the same elevation, and had similar lengths and depths. A more detailed investigation led the licensee to conclude that these indications are a result of tube wear due to tube-to-tube contact. The length of these wear indications ranged from 5 centimeters to 20 centimeters (2 inches to 8 inches) and the depths ranged from 1 percent to 21 percent through-wall.

As a result of these findings, the licensee for TMI-1 informed the licensee for Arkansas Nuclear One, Unit 1 (ANO-1), since ANO-1 has similar steam generators. At the time, ANO-1 was shut down for a refueling outage. However, the steam generator tube inspections had been completed.

The original once-through steam generators at ANO-1 were replaced in 2005. AREVA (France) also fabricated the replacement once-through steam generators at ANO-1, which are similar (but not identical) to those used at TMI-1. Based on the information provided by the licensee for TMI-1, the ANO-1 licensee reevaluated its previously recorded eddy current data and determined it had similar indications of wear as a result of tube-to-tube contact. Some of these indications were traceable to the first inservice inspection of ANO-1's steam generators in 2007. The characteristics of the tube-to-tube wear indications at ANO-1, including the depth and length, are similar to those at TMI-1. In addition, two neighboring tubes have wear indications in two spans rather than one at ANO-1.

Given that these tube-to-tube wear indications were not originally classified as tube-to-tube wear, the licensee for ANO-1 performed an apparent cause evaluation. They determined several contributing factors as to why these indications were not identified: (1) the absence of a differential channel response to indicate a flaw-like condition, (2) not reporting, mischaracterizing, or deleting the absolute indications by the eddy current analysts, and (3) distractions to the analysts because of observing bowing of the tie rods used to support and connect the tube support plates.

Investigations into the cause of the tube-to-tube contact at ANO-1 and TMI-1 are ongoing.

In the spring of 2012, the licensee for Oconee, Unit 3 also detected wear attributed to tube-to-tube contact in their replacement once-through steam generators. These steam generators were designed and fabricated by Babcock and Wilcox in Canada and were installed in 2004. The AREVA and Babcock and Wilcox once-through steam generators are similar, but not identical. The indications of wear attributed to tube-to-tube contact at Oconee, Unit 3 are generally located in the center of the tube bundle, the region of highest compression. The length of the wear indications ranged from 2.5 centimeters to 23 centimeters (1 inch to 9 inches), and the depths ranged up to 20 percent through-wall. All but one of the indications of wear attributed to tube-to-tube contact were traceable to the first inservice inspection of the Oconee, Unit 3's steam generators in 2006. The licensee indicated that criterion used by eddy current analysts to report a tube-to-tube wear indication in prior outages was the indication had to have a voltage greater than 0.5 volts on one channel, and the indication's depth on a second

channel had to measure within 10 percent of the through-wall depth measured on the first channel. During the 2012 inspection, this criterion was changed to only require that the indication be present on the second channel. The licensee believes the tube-to-tube contact is due to compression of the tubes in the region where the indications were observed. Discussions with the steam generator manufacturer are on-going.

The licensees for ANO-1, Oconee, Unit 3, and TMI-1 evaluated the severity of the tube-to-tube wear indications in their steam generators. These evaluations concluded that the wear indications did not compromise tube integrity (i.e., the tubes could still perform their intended function consistent with their original design and licensing basis). The licensees also concluded that they could operate until their next scheduled inspection with the wear indications left in service without compromising tube integrity.

BACKGROUND

NRC IN 2002-21, "Axial Outside-Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing," dated June 25, 2002, highlighted, in part, the importance of being alert during inspections to evidence of possible stress corrosion cracking, regardless of how long the steam generators have been operating. NRC IN 2002-21 can be found on the NRC's public Web site in the Agencywide Documents Access and Management System (ADAMS) at Accession No. ML021770094.

NRC IN 2003-05, "Failure to Detect Freespan Cracks in PWR [Pressurized Water Reactor] Steam Generator Tubes," dated June 5, 2003, highlighted, in part, that the bobbin coil eddy current data from the absolute channel can be helpful in detecting long freespan indications and observing changes in signals over time (ADAMS Accession No ML031550258).

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, highlighted, in part, difficulty in detecting new or unexpected forms of degradation (ADAMS Accession No. ML102210244).

DISCUSSION

Technical specifications require steam generator tubes to be inspected. Furthermore, 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 used and at what locations. The objective is to detect flaws of any type that may satisfy the applicable tube repair criteria. Tube-to-tube contact and the resultant wearing of the tubes are not expected to occur in steam generators. The reevaluation results of the eddy current data at ANO-1 and Oconee Unit 3 illustrate the difficulties in identifying new or unexpected forms of degradation and the importance of performing robust inspections that will detect both expected and potentially new or emerging degradation mechanisms. IN 2010-21 highlighted the difficulty of identifying a new form of degradation. IN 2002-21 indicated that the steam generators with the most severe operating conditions (e.g., operating time) may not be the first plant at which degradation is observed.

The successful identification of wear because of tube-to-tube contact at TMI-1 indicates that a comprehensive review of the locations and characteristics of all detected eddy current indications may be an effective diagnostic tool for evaluating inspection data. This comprehensive review may include plotting all locations where indications have been detected both radially within the steam generator tube bundle and axially along the tube length. It may involve reviewing all indications together or looking at subsets of various types of indications. It

may also include determining the directions the indications face and plotting changes in signal amplitudes to determine if the indications are changing with time. Performance of the comprehensive review may, for example, reveal a clustering of eddy current indications or another pattern that may warrant additional attention (e.g., migration of a loose part left in a steam generator or the tube-to-tube wear phenomenon).

The ANO-1 and TMI-1 inspections highlight the importance of reviewing data from the absolute channels in addition to data from the differential channels. Slowly varying flaws such as long-tapered wear scars and cracks may not be detectable on the differential channels. However, they may create clearly discernible signals on the absolute channel. The usefulness of reviewing data from the absolute channel was discussed in IN 2003-05.

The indications at ANO-1 may have been characterized earlier as wear flaws if a more comprehensive comparison was performed of the data obtained during the preservice and first inservice inspection of the tubes. Since none of the tube-to-tube wear indications were present in the preservice inspection, there was clearly a change in the eddy current data. The difficulty of attributing this clear change in eddy current data to tube degradation, however, is that some of this change also could be the result of operating the tubes at temperature for a cycle (i.e., the first heating of the tubes) and normal test repeatability. This highlights the importance of understanding the magnitude of the change in eddy current signals that typically occur as a result of the first heat cycle and test repeatability so that any higher-than-normal changes can be further investigated as possible indications of tube degradation.

The findings at Oconee Unit 3 demonstrate the importance of properly establishing the reporting criteria used by eddy current analysts to ensure flaws are identified. In addition, the findings at Oconee Unit 3 demonstrate the importance of using operating experience since the results from TMI-1 and ANO-1 were used to target the inspections at Oconee Unit 3 to detect tube-to-tube wear indications. The ANO-1 findings also highlight the importance of staying attentive to all inspection results and not only focusing on specific issues.

From a broader perspective, the ANO-1 and TMI-1 findings highlight the importance of performing comprehensive inspections of new and replacement equipment to ensure that it is performing as expected.

CONTACT

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

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