UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

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NRC INFORMATION NOTICE 2003-05: FAILURE TO DETECT FREESPAN CRACKS IN PWR STEAM GENERATOR TUBES

Addressees

All holders of operating licenses or construction permits for pressurized-water reactors (PWRs).

Purpose

This information notice (IN) is being provided to inform licensees of a recent problem experienced at Comanche Peak Unit 1 concerning the detection of freespan outside diameter stress corrosion cracking (ODSCC) in steam generator (SG) tubes. This has led to tube integrity performance criteria not being met as defined in Nuclear Energy Institute (NEI) 97-06, "Steam Generator Program Guidelines." The NRC anticipates that recipients will review the information for applicability to their facilities and consider taking appropriate actions. However, suggestions contained in this IN do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

Comanche Peak Unit 1 is a four-loop Westinghouse PWR with four Westinghouse Model D4 recirculating SGs (1, 2, 3, 4). Each SG contains 4578 mill- annealed Alloy 600 tubes, which are nominally 0.750 inch in diameter and have a nominal wall thickness of 0.043 inch. The tubes are supported by a number of carbon steel tube support plates with circular holes and by V-shaped chrome-plated Alloy 600 anti-vibration bars (AVBs).

Comanche Peak Unit 1 was shut down approximately 1 week prior to its scheduled refueling outage as a result of a primary-to-secondary leak. A 5- to 15-gallon-per-day (gpd) leak was first observed in SG 2 on September 26, 2002. Over the next 2 days, the leakage spiked to higher values several times. On September 28, 2002, after a leakage spike to 52 gpd, the licensee elected to shut down the plant and to commence refueling (1RF09). In response to the leak, a special inspection by the NRC staff was conducted. The results of the special inspection were documented in an inspection report dated January 9, 2003, "Comanche Peak Steam Electric Station - Special Team Inspection Report 50-445/02-09" (ADAMS Accession No. ML030090566).

After shutting down the plant, the licensee began inspecting the SG tubes with eddy current testing techniques. A bobbin coil and a rotating probe were used during these inspections. The rotating probe was equipped with various types of coils including a +Point™ coil. The bobbin coil was used to inspect the full length of each tube while the rotating probe was used to inspect selected regions of the tube (e.g., the top of tubesheet region) and to confirm and/or characterize indications initially detected by the bobbin coil probe.

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The licensee determined that the leak was from an axially oriented flaw in the tube located at row 41, column 71 (R41C71) in SG 2. The flaw, located in the U-bend region, was estimated from the +Point™ coil to be approximately 0.9 inches in length, with a depth of approximately 90 percent over most of the indicated length. The licensee's structural assessment of the flaw indicated that the leaking tube did not meet the applicable structural and accident leakage performance criteria in NEI 97-06. These performance criteria were developed consistent with the plant design and licensing basis and include the three-times-normal-operating-pressure criterion against burst (3800 pounds per square inch (psi)), the 1.4 times main steam line break (MSLB) criterion against burst (3584 psi), and a 1- gallon-per-minute (gpm) MSLB- induced leak rate criterion. The licensee estimated the burst pressure of R41C71 to be 2727 psi at the location of the flaw based on analysis of the flaw profile as determined by the +Point™ coil. In situ pressure testing of this tube was terminated at a test pressure of 2100 psi when leakage exceeded the test system capacity of 2.5 gpm.

Review of the bobbin data for this tube (R41C71) from the previous inspection in 2001 (1RF08) revealed that a clearly detectable indication was present at the location of the leak. This bobbin indication did not meet the reporting criteria in the 1RF08 eddy current data analysis guidelines and was not reported by either the primary or the secondary analyst in 2001. These reporting criteria required a freespan bobbin indication in the absence of a dent or ding signal to be reported if the phase angle response of the indication was less than the phase angle response corresponding to a 0 percent through-wall flaw. Since a dent or ding signal can rotate a flaw signal out of the normal phase angle window, the applicable reporting criteria for bobbin indications in the presence of a detectable dent or ding signal were less restrictive (i.e., were increased). If a dent or ding signal had been reported at this location in 1RFO8, the bobbin indication in tube R41C71 would have been reportable. A reportable bobbin indication might have triggered additional inspections with a rotating probe. However, no ding signal was reported at the R41C71 location in 1RF08 by either the primary or the secondary analysts during their review of the bobbin data since there was no clear evidence of a ding in the 1RF08 signal response. However, a large amount of horizontal noise attributable to probe wobble was observed. This amount of horizontal noise could easily mask a 2 volt ding signal.

Based on these findings, the licensee revised its bobbin probe data analysis procedures for the 1RF09 inspection to increase the phase angle response reporting criteria for freespan indications. The ensuing inspections identified about 20 freespan flaws. These included freespan flaws associated with dents and dings and long freespan flaws not associated with dents or dings. However, examination of the inspection results called into question the reliability of the bobbin inspection. Of the 20 freespan flaws, only 5 had been detected during both the primary analysis of the bobbin data, performed using automated (computerized) data screening (ADS), and the secondary analysis of the bobbin data, performed by human analysts. The primary (ADS) analysis missed several of the bobbin indications called by the secondary (human) analysis and vice versa. In general, the bobbin indications missed by the primary (ADS) analysis exhibited bobbin amplitude responses less than the 0.2-volt ADS threshold. Furthermore, 8 of the 20 freespan flaws were not detected by either the primary or secondary analysis of the bobbin data. These eight freespan flaws were found fortuitously rather than by programmatic intent. They were found only because the licensee had performed a more comprehensive +Point™ examination of the region to investigate an indication or dent located elsewhere in the same region of tube where the flaw was eventually found.

Accordingly, the licensee retrained the analysts and manually performed a third (tertiary) independent analysis of the bobbin coil data, leading to the finding of additional freespan bobbin indications. Several of these additional freespan bobbin indications were confirmed as flaws during the +Point™ coil examination. Of these confirmed flaws, two had been detected during the aforementioned primary and/or secondary analysis of the bobbin coil data. These bobbin indications were not investigated with a +Point™ coil following the primary (ADS) and secondary (manual) analysis since the bobbin signals at these locations were perceived to be similar to those observed in 1999 (i.e., there was a perceived lack of change in the bobbin coil signal indicating that the bobbin indication was not a result of a flaw, but rather it was within the expected range of repeatability of the bobbin test). However, during the tertiary analysis, the review of the prior inspection data for these indications revealed clear indications of signal change, calling into question the effectiveness of the prior history reviews for bobbin indications.

To address this concern, the licensee prepared data analysis guidelines for the history reviews and performed a new, supplemental history review of all bobbin indications. Two qualified data analysts working as a team performed this supplemental review. They considered all data extending back to the first inservice inspection, including data from the low-frequency absolute channel. The analysts were also instructed to identify not only indications with changes exceeding change criteria specified in the data analysis guidelines, but also indications with changes which, in their experience and judgment, were beyond changes associated with normal eddy current signal repeatability. This review led to the finding of three additional flaws.

<u>Discussion</u>

Early detection of stress corrosion cracks is key to ensuring that such cracks do not impair tube integrity relative to the tube integrity performance criteria in NEI 97-06. It continues to be standard industry practice to use bobbin probes to screen for indications potentially associated with axially oriented stress corrosion cracks and, where such indications are found, to perform a followup inspection with a rotating, surface-riding coil such as a pancake or +Point™ coil to determine whether a crack is actually present. As evidenced by the recent experience at Comanche Peak Unit 1, appropriate data analysis procedures, analyst training, and process controls are critical to ensuring that all indications of actual stress corrosion cracking are being identified during the bobbin coil data analysis and subsequently inspected with a +Point™ coil. The following are some of the lessons learned from the recent experience at Comanche Peak Unit 1.

1. Care should be exercised when establishing reporting criteria for indications based on phase angle response. Dings, dents, and other artifacts can rotate a flaw indication outside the nominal range of phase angle response, even where the amplitude of such artifacts is relatively small or less than the reporting value for such artifacts.

2. The presence of artifact signals which may potentially distort flaw indications can themselves be masked by other artifacts such as probe wobble. Probe wobble signals tend to be particularly large in the U-bend region of a tube.

3. Depending on the value of the threshold criteria, indications with voltage responses less than the ADS threshold criteria may sometimes be associated with flaws whose maximum depths exceed the tube plugging limit (e.g., 40 percent through-wall). Thus, data analysis procedures (including ADS threshold criteria) should be sufficiently robust

to reliably identify indications which may potentially exceed the plugging limit. For example, the use of ADS at some plants is supplemented by an independent review of the data by two teams of human analysts.

4. A comparative review of indications called by the primary and secondary analysis teams can provide insights on the effectiveness of the analysis effort. As an illustration, failure of the primary or secondary analysis team to detect a high fraction of the indications identified by the other team may be indicative of a need to evaluate the cause of the discrepancies and whether corrective actions are needed with respect to the examination technique, data analysis guidelines, and/or analyst training.

5. A robust approach is important for determining which bobbin indications exhibit change over time in order to ensure all potential flaws are further evaluated (e.g., with a rotating probe). A team could review the previous bobbin coil data for each indication identified during an inspection or multiple independent reviews of the previous bobbin coil data could be done. The analysts might be allowed to use their judgment and experience in determining whether there has been a change in addition to determining whether specific change criteria on phase angle and amplitude have been met. In addition, previous inspection data could be reviewed as far back in time as possible since the bobbin response for some of the flaws at Comanche Peak Unit 1 did not show a change when compared only to the most recent previous inspection data.

6. The bobbin data from the low-frequency absolute data channel can sometimes be helpful in detecting long freespan indications and for observing changes in these signals over time.

7. The insertion of known flaw signals from a “Judas” (or “Cobra”) tube into the data stream being reviewed by each data analyst can provide additional confidence in the performance level of the analysts. This insertion could be done in such a manner that the data analysts could not tell that the inserted flaw signal did not belong to the population of actual flaws they were currently analyzing. At Comanche Peak Unit 1, the Judas tube was a tube containing indications missed during the primary and secondary analysis and found fortuitously during the subsequent +Point™ examination.

Related Generic Communications

The following documents describes other recent reactor operating experience with steam generator tubes:

1. IN 2002-02 and IN 2002-02 supplement 1, “Recent Experience With Plugged Steam Generator Tubes” dated January 8, 2002 and July, 17, 2002

2. IN 2002-21, “Axial Outside-Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing” dated June 25, 2002

3. IN 2001-16, “Recent Foreign and Domestic Experience with Degradation of Steam Generator Tubes and Internals,” dated October 31, 2001

4. NRC Generic Letter 97-05, “Steam Generator Tube Inspection Techniques,” dated December 17, 1997

This information notice does not require any specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate project manager in the NRC's Office of Nuclear Reactor Regulation (NRR).

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Attachments: List of Recently Issued NRC Information Notices