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Region IV
611 Ryan Plaza Drive, Suite 400
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Subject: Arkansas Nuclear One - Unit 2
Docket No. 50-368
License No. NPF-6
Special Report: Steam Generator Tube Surveillance - Category C-3 Results

Gentlemen:

The steam generator tubing inservice inspection of the Arkansas Nuclear One, Unit 2 (ANO-2), steam generators (SGs) was performed during the eleventh refueling outage (2R11). The inspections performed on both SGs were a 100% full length bobbin coil examination, a 100% rotating eddy current probe (RECP) inspection in the hot leg (HL) expansion transition (ET) region, a 20% RECP inspection of the cold leg ET region bounded by the sludge pile (later expanded to 100% of the tubesheet in the "A" SG), a 100% inspection of existing installed sleeves using a plus point probe, and a 20% inspection of row 1 small radius U-bends using the plus point probe. The RECP used was designed by Entergy, ABB-CE, and Zetec personnel and consists of a probe with a 0.115 inch pancake coil and 2 plus point coils. The centerline frequencies of the three coils are 400, 240, and 440 KHz respectively. The bobbin coil inspection was performed to meet the requirements of ANO-2 Technical Specification (TS) 4.4.5.2. The RECP inspection was utilized at the region of interest for the detection of circumferential cracking, which is virtually undetectable with the bobbin coil probe.

The results of these inspections revealed 656 defective tubes in the "A" SG (SGA) and 334 defective tubes in the "B" SG (SGB). Consequently, both the SGs fall within the criteria of Category C-3 (more than 10% of the total tubes inspected are degraded tubes or more than 1% of the inspected tubes are defective), as defined in ANO-2 TS 4.4.5.2.c. Tables 1 and 2 summarize the results of these inspections. ANO-2 TSs 4.4.5.5.c and 6.9.2.j require that a Special Report be submitted prior to resumption of plant operation for inspections that fall into Category C-3. This submittal provides the required report and reflects information provided to the Staff during our October 12, 19, 31, and November 6, 1995 teleconferences.

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PLANT DESCRIPTION

ANO-2 is a Combustion Engineering (CE) Model 2815 designed plant that began commercial operation in March, 1980. The plant has two recirculating SGs, each having 8411 high temperature mill annealed Inconel Alloy 600 tubes with a 0.75" outer diameter and a 0.048" wall thickness. The tubes were full depth explosively expanded into the tubesheet. The tube supports in the lower part of the SG are eggcrate (EC) type which consists of an array of intersecting one inch wide and two inch wide flat carbon steel plates at each support elevation. There are seven full EC support plates, two partial EC support plates, two partial drilled support plates, and five strap supports for the horizontal run of the tubing, called batwings (BW). The BW supports consist of two diagonal and three vertical straps.

INSPECTION RESULTS

Since 100% bobbin, HL ET region, and sleeve inspections were performed as the first sample for each SG, no expansion was required as a result of the C-3 inspection results. The SGA first sample (20%) cold leg sludge pile inspection was expanded to 100% of the ET region, even though the first inspection was Category C-2.

The inspections were performed from both the hot and cold leg sides of both SGs. In SGA, 639 tubes were found to have indications requiring repair, due to either exceeding the repair limit of 40% throughwall (TW), exhibiting flaw-like distorted indications, or containing circumferential indications in the ET region. All distorted indications confirmed by the RECP as flaw-like were repaired. The 656 tubes contained 691 repairable indications as detailed in Table 2. In SGB, 334 tubes were found to have indications requiring repair, due to either exceeding the repair limit of 40% TW, exhibiting flaw-like distorted indications, or containing circumferential indications in the ET region. All distorted indications confirmed by the RECP as flaw-like were repaired. The 334 tubes contained 349 repairable indications as detailed in Table 2.

The ET region indications were primarily circumferential cracks with some axial cracking present in a few tubes. The eggcrate indications were predominantly axial cracks based upon observations from previously pulled tubes. Sludge pile indications are generally considered to be axial and volumetric in nature. The BW flaws found consisted mostly of wear attributed to flow induced vibration across the horizontal portion of the tubing at the upper support structure. The inservice tubes containing previously installed sleeves revealed indications in the parent tubes classified as non-quantifiable indications (NQIs). No indications were found in the 20% examination of the small radius U-bends performed in row 1.

EVALUATION OF INSPECTION RESULTS

Three major changes were incorporated during 2R11 to improve the data and enhance the detection and sizing of indications. The first change was the use of a probe containing two plus point coils, along with a 0.115" pancake coil. Previously, only the standard three coil pancake probe was used in the ET regions. The second change was the use of the plus point probe for sleeve analysis. The plus point coil provides enhanced detectability over the pancake coil because it is less sensitive to geometric changes. The probe was used at settings specified in the EPRI SG NDE Guidelines, Appendix H, to provide optimum results. The third change was the use of 10D probe pushers and MIZ-30 controllers which provided enhanced data quality. As a result of these changes, detectability of flaws was improved over that attained in previous inspections.

Based on the examination results of the tubes pulled in the Spring 1992 forced outage (2F92), the damage at both the eggcrate support plates and the ET region is stress corrosion cracking (SCC). Sulfur was believed to be a major contributor. In addition, lead was found in the cracks and in the tube deposits. Minor intergranular attack (IGA) occurs with the SCC.

CIRCUMFERENTIAL CRACKING

This was the sixth inspection of the ET region with a RECP. The average size (both length and depth) of the cracks has generally decreased in successive outages, as shown in Figure 1. The increased number of circumferential cracks detected may be a result of the advances in eddy current technology. Based on studies performed by Entergy and pulled tubes from other utilities, the threshold of detection of the plus point coil is clearly lower than that of the pancake coil, thus resulting in the detection of smaller indications which would have previously gone undiscovered. The following data illustrates the changes in technology and the corresponding number of indications.

Outage		# Cracks	Avg. Length, Deg.	Avg % TW	Detection Probe and Coil
2F92	(3/92)	469	115	24.0	.080 MRPC
2R9	(9/92)	25	90	18.4	.080 MRPC
2P93	(5/93)	48	89	17.2	.080 MRPC
2R10	(3/94)	170	82	16.1	.115 MRPC, low loss cables
2P95	(1/95)	283	85	17.0	.115 MRPC, MIZ-30, low loss cables, terrain maps utilized
2R11	(9/95)	702 *	69	11.6	Plus Point, MIZ-30 App. H settings, low loss cables, terrain maps utilized

* Only includes the hot leg circumferential cracks. Total number including the cold leg is 738. Inclusion of cold leg cracks would reduce avg %TW and avg length values.

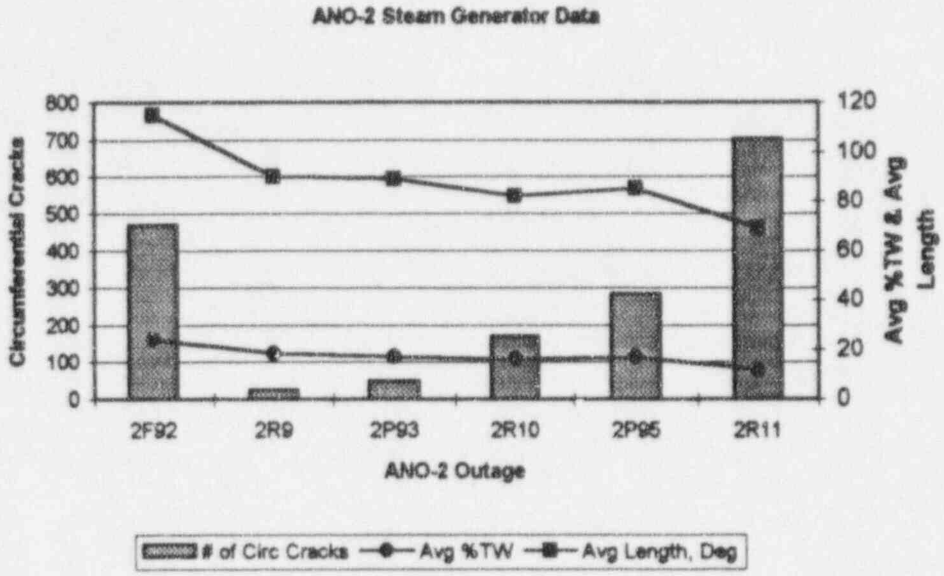

Figure 1

The average % TW (average depth) shown above is calculated based on the maximum depth and arc length. Average depth can also be viewed as the crack "area" and is indicative of the structural limit of the flaw. This has been demonstrated by numerous burst tests in the industry and as detailed in a report submitted to the NRC titled 'Repair Limit for Circumferential Cracks in Steam Generator Tubing" dated August 28, 1995 (2CAN089507). During the 2R11 examination, the largest crack was determined to be 71% average depth. In terms of structural adequacy to meet Regulatory Guide (RG) 1.121, based on a limiting differential pressure of 4050 psig (3ΔP), a 79% average crack would maintain the required safety margin. This conservative approach takes no credit for partial depth crack extent or ligaments which are expected to be present based on typical stress corrosion crack morphology.

Based on documented burst testing data, all 738 circumferential cracks in 2R11 would be expected to exhibit burst pressures significantly above that required by RG 1.121, with most being at or near that of a virgin tube.

To further assess the structural significance of the flaws, in-situ pressure tests were conducted. The three largest and the fifth largest ET region circumferential cracks were selected for testing. The pressure test device utilizes two expandable bladders approximately 3.5" apart, and allows the chamber between the bladders to be pressurized up to 7000 psig. The device is designed to allow movement of the region between the bladders such that the axial load that would be applied to the U-bend of the tube during normal operation and postulated accident conditions is simulated for circumferential cracking.

The four tubes selected for testing were based on their size and physical location in the SG to allow testing from one fixture location due to ALARA considerations. The results are summarized below:

TUBE	Max. Pressure (psig)	Leakage
77-83	≈6800	None
68-106	≈6800	None
87-67	≈6800	None
41-65	≈6800	None

Each tube was tested at four different pressures as follows:

Step One	≈1650 psig	(ΔP)
Step Two	≈2950 psig	(Peak accident pressure)
Step Three	≈4750 psig	($3\Delta P$)
Step Four	≈6800 psig	(Maximum pressure)

These values were obtained by adjusting the desired values by 1.15 to compensate for temperature in accordance with the CE Owners Group Steam Generator Tube In-Situ Pressure Testing Guidelines and adding 50 psig (1/2% full scale) for instrument tolerance. Final values were rounded up to the nearest 50 psig increment. Based on peak test pressure, all tubes met the requirement of $3\Delta P$ (4050 psig).

AXIAL CRACKING (EGGCRATE)

Cracking at eggcrates was first detected at ANO-2 in 1991. Based on the examination results of tubes removed during 2F92, the eggcrate support indications are classified as axially oriented stress corrosion cracking. The cracking can be single cracks or multiple cracks interconnected in the tube within the eggcrate support. The distribution of axial eggcrate cracks 20% and greater is shown in Figure 2 for SGA and Figure 3 for SGB.

2R11 Bobbin Data
SG A Eggcrate Crack Amplitude

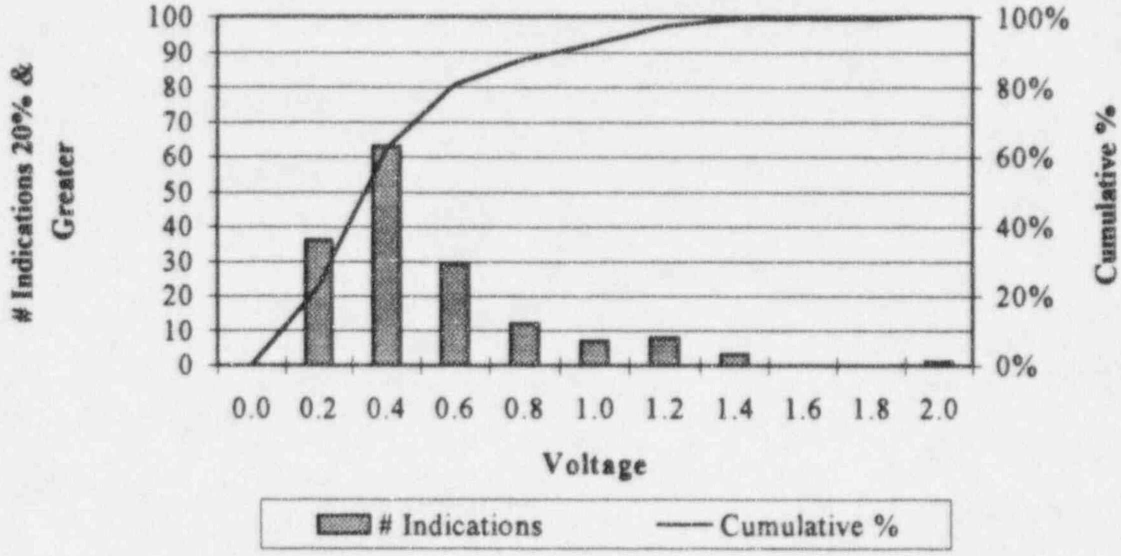

Figure 2

2R11 Bobbin Data
SG B Eggcrate Crack Amplitude

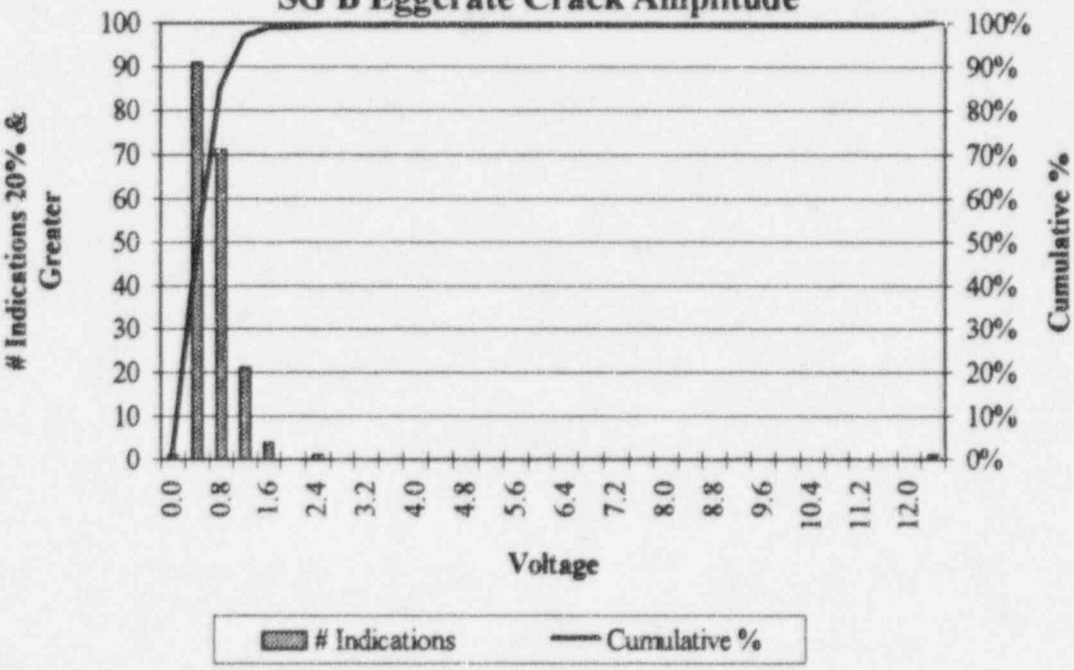

Figure 3

In 2R11, the average size of all eggcrate indications 20% and greater was 0.56 volts. While not identical, these voltage readings are comparable to those utilized for cracking at drilled tube support plates at Westinghouse designed plants. Thus, a comparison of burst test data for Westinghouse plants vs. voltage can be made and assessments of structural significance for amplitude values at ANO-2 can be performed. These comparisons show that eggcrate cracks at ANO-2 have historically been structurally insignificant. In addition, burst testing of eggcrate cracks of tubes removed in 1992 from ANO-2 were found to exhibit burst pressures in excess of 8000 psig, which reasonably agrees with the Westinghouse plant data.

One eggcrate flaw in SGB was found by bobbin and appeared to be an exception based on its size. The flaw was sized by bobbin at 12.21 volts and 86% TW. This flaw was analyzed using the plus point probe and was sized to be 90% TW. Average voltages suggest this was an isolated case. All other flaws exhibited expected results. An in-situ test of this flaw was performed at 3 different pressures as shown below:

			Leakage
Step One	≈1650 psig	(ΔP)	≈0.005 GPM
Step Two	≈2950 psig	(Peak accident pressure)	≈0.4 GPM
Step Three	≈1650 psig	(ΔP)	≈0.32 GPM
Step Four	≈4700 psig	(3ΔP)	N/A

The leakage values shown above are as-measured and have not been compensated for temperature. When temperature compensated, the leakage would decrease, thus indicating that the measured values are conservative.

The tube was first pressurized to 1650 psig and a leakrate was observed that was comparable to that seen prior to shutdown. The pressure was then raised to 2950 psig where the leakrate increased to 0.40 GPM. A bladder was then placed over the flaw and pressurized up to 4700 psig. A visual examination following the pressure test was performed which revealed that two parallel axial cracks were present. Based on its peak pressure, this tube met the 3ΔP (4050 psig) guidance of RG 1.121.

AXIAL CRACKS (FREE-SPAN)

Several indications were identified during the bobbin coil inspection as non-quantifiable indications (NQIs) and were subsequently examined using the plus point probe. Two of these were located in rows 1 and 2 and were determined to be axial crack-like indications found in the free-span region below the U-bend tangent (not previously identified at ANO-2) and are bounded in elevation by the 4th through 7th eggcrates on the hot leg side. Because of concerns from the experience at Palo Verde about the ability of the bobbin coil to adequately detect free-span cracks, further investigation was warranted, and resulted in expanding the scope of the plus point examination to include 100% of the tubes in rows 1-3 from the stay cylinder out to line 167, with an additional 100 tube random inspection of rows 4-20 in the same area. Additionally, any tubes exhibiting free-span bobbin indications greater than 0% TW in SGA were examined. These tubes (83) were distributed throughout the bundle at various elevations. Additionally, the bobbin data foi rows 1-20 was re-evaluated with the objective of identifying any potential flaws. This re-evaluation yielded approximately 300 tubes with shallow indications on the low frequency channels. A total of 510 tubes were analyzed identifying 16 tubes with 18 indications (9 which were previously identified by bobbin, and 9 detected during the random inspection). A re-evaluation of the bobbin data for these 9 detected by the random inspection showed them to be low amplitude (0.08-0.65 volts) with a maximum TW value of 17 %. The largest of the 18 flaws was one of the original two identified as a NQI and measured 1.9 volts and was approximately 1.85 inches in length. The tubes not originally flagged by bobbin are considered to be non-consequential indications with percent through wall depths much less than the repair limit, none of which were reportable as defined by the Technical Specifications. Overall, the bobbin examination technique was judged to be highly effective in the detection of free-span indications based on plant-specific studies at ANO-2 in that all tubes with detectable rotating probe indications also exhibited detectable bobbin indications.

A full length in-situ pressure test of the tube containing the largest free-span indication was performed. The tube was tested at 3 different pressures as detailed below:

			Leakage
Step One	≈1650 psig	(ΔP)	None
Step Two	≈2950 psig	(Peak accident pressure)	None
Step Three	≈4750 psig	(3ΔP)	None

Based on the peak pressure, this tube met the 3ΔP (4050 psig) guidance of RG 1.121.

CONCLUSIONS

In summary, a comprehensive eddy current examination was performed during 2R11. Both SGs were tested 100% full length with the bobbin coil, 100% at the hot leg ET region with RECP, 100% of the SGA cold leg ET region, 20% of the SGB cold leg ET sludge pile region, 100% of the existing installed sleeves, a 20% inspection of row one small radius U-bends, and an expanded inspection of areas containing free-span indications. The analysts conservatively reported all potential flaws detected and utilized no defined threshold criteria. Diagnostic RECP was used to further evaluate ambiguous bobbin signals. All tubes exhibiting flaws ≥ 40% TW, distorted signals, or circumferential cracks were repaired.

The 738 circumferential cracks detected in 2R11 exhibited a size distribution comparable to those in previous outages. The increased number is primarily attributed to the utilization of more sensitive equipment and analysis techniques. These cracks would be expected to exhibit burst pressures well above that required by RG 1.121. The in-situ pressure tests of the largest flaws demonstrated that the flaw strengths exceeded 3ΔP.

With respect to the axial cracks detected during 2R11, all but one of the eggcrate axial crack sizes were in the expected range. These cracks would be expected to exhibit burst pressures above that required for structural adequacy as defined in RG 1.121. The largest crack was successfully in-situ pressure tested at a pressure of ≈3ΔP. Free span cracks were first identified this outage and are readily identified by bobbin coil. Those that were not originally identified by bobbin are insignificant in size. Structurally, the largest of these flaws would be expected to burst at pressures well above that required by RG 1.121 as demonstrated by in-situ pressure testing and analytical evaluations.

The cause of the free-span cracking seems to be associated with the buildup of deposits in the area of tubing between the fourth and the seventh support plates. During the period of time from 2R9 to 2R10, levels of deposits are evident but very minor as indicated by eddy current data. An increase in the amount of deposits was noted, again from eddy current data, by comparing the deposits present this outage versus last outage. The cracks seem to be associated with these deposits.

Various actions were taken in the past to mitigate the circumferential cracking at the ET region. They were:

1) Reduce T_{Hot} from 607 to ≈600 degrees.

2) Use alternate amines to minimize iron transport (morpholine, ethanolamine).

3) Adjust boric acid treatment for the secondary side.

4) Initiate molar ratio control.

An evaluation of these and other changes is ongoing to determine the effects on deposition in this area of the generator. Entergy will evaluate these results to determine if corrective actions need to be made.

ANO-2 utilizes N-16 monitors for primary-to-secondary leakage detection, and has an administrative leakage limit of 0.1 GPM (144 GPD). Abnormal operating procedures are in place for both Operations and Chemistry in the event that leakage is detected. Other leakage monitors include condenser off-gas radiation monitor, steam generator blowdown monitor, main steam line radiation monitors, in addition to the utilization of blowdown grab samples. Entergy Operations is sensitive to the potential rapid progression of tube leakage and will take the necessary measures upon detection, should a primary-to-secondary leak occur. Operations routinely trains on primary-secondary leaks and tube ruptures utilizing the simulator.

Based upon the comprehensive actions performed during 2R11 in conjunction with the ability to rapidly detect and respond to any primary-secondary leakage, as described above, Entergy Operations believes ANO-2 is safe to resume plant operation.

Should you have any questions regarding this submittal, please contact me.

Very truly yours,

Dwight C. Mims

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Director, Nuclear Safety

DCM/jjd

attachment

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TABLE 1

2R11 INSPECTION SCOPE

	SGA	SGB
# Tested Bobbin Coil	7867	7994
# Tested RECP Hot Leg ET region	7480	7939
# Tested RECP Cold Leg ET region	7867	1029
# Sleeves Tested	387	55
# Tested Row 1 Small Radius U-bends	12	12
Tech. Spec. Inspection Results Category	C-3	C-3

TABLE 2

2R11 FLAW LOCATIONS

LOCATION	SGA	SGB
Hot Leg ET Region (circumferential)	487	215
Hot Leg Sludge Pile	43	23
Cold Leg ET Region (circumferential)	36	0
Cold Leg Sludge Pile	37	1
EC Support Plate	47	85
BW Support	2	19
Drilled Support Plate	0	2
Sleeved Tubes	17	4
Free-Span	18	0
Miscellaneous	4	0
Total	691	349