OAK RIDGE NATIONAL LABORATORY
OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831

February 21, 1992

Mr. Emmett L. Murphy
Office of Reactor Regulation
Materials Engineering Branch
U.S. Nuclear Regulatory Commission
MS WFN-9H15
Washington, DC 20555

Dear Emmett:

On February 4, 1992, I traveled to the McGuire Nuclear Station Unit 1, near Charlotte, North Carolina. This plant, operated by Duke Power, is a 1180-MW electrical plant and has four Westinghouse Model D-2 Steam Generators. This plant went into operation about 1980, and soon experienced problems with fretting in the preheater section as did other model D2, D3, and to a lesser extent, D4 steam generators.

Tube rupture in 1989 On March 7, 1989, McGuire experienced a tube rupture that resulted in a 540 gallon-per-minute leak in the B Steam Generator. It was determined that tube R18C25 had ruptured in the free span of the tube near support plate 20, in the cold leg of the generator. Metallography of the tube revealed a series of cracks about 7 1/2 in long and identified as intergranular stress corrosion cracks (IGSCC). The cracks ran in both the axial and circumferential directions in a lattice along the tube. The major crack was axial, with a small network of shallow circumferential cracks. At the time it was concluded that this tube was a "rogue" tube and the phenomenon was not expected to occur again. The last inspection of this tube before the rupture was the baseline performed in 1978 with an EM 3300 single frequency instrument driving a 0.590 differential bobbin probe. No signal was visible on the baseline scan. A testing program including 100% inspection of all tubes with a 0.610 diameter probe was recommended to eliminate this type of occurrence.

Tube leak in 1992 On December 12, 1991, after a refueling outage, McGuire 1 was restarted. On January 16, the plant was brought down due to a tube leak of 235 gallons per day. This leak was determined to be in the free span of tube R47C46 in steam generator D, between the 20th and 19th tube supports in the cold leg. The defect had been detected at the 1991 outage, erroneously

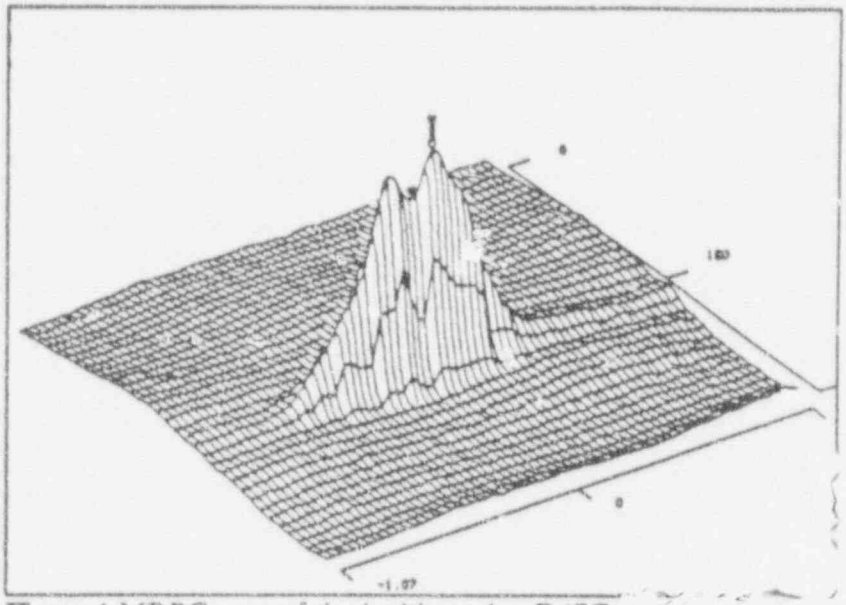

Figure 1 MRPC scan of the leaking tube, R47C46

classified as a manufacturer's burnishing mark (MBM), and ignored. The tube had also been inspected using the MRPC, but the results had not been reviewed by the proper personnel before the unit was returned to power. The defect in tube R47C46 in generator D was very similar to the tube R18C25 in generator B, with the exception that the plant was shut down before a tube rupture due to the new, more stringent leak rate rules. A plot of the MRPC scan of tube R47C46 made after the leak is shown in Figure 1.

Growth rate of the defect McGuire 1 has used 100% bobbin coil inspection of the full length of the tube since the 1989 tube rupture. The 1990 inspection, the last one before the 1991 inspection that detected the defect, showed no trace of the defect at the location of the leak. There was a possible precursor indication of the 35 Khz absolute channel that could have been caused by a ferromagnetic deposit on the tube or a ferromagnetic region of the tube, but the signal could also be due to random noise. Several indications were also found in the leaker tube near the 15th tube support. There was no sign of these indications either on the 1990 scan of the tube, indicating that they were of the same fast growing phenomenon. On the basis of the lack of a signal in 1990, the phenomenon could grow in as fast as several week's time to full wall penetration. The eddy-current depth measurement made using the 400kHz differential signal from the bobbin probe during the 1991 outage was 85%, with a voltage amplitude of 1.7 volts, as shown in Figure 2. The depth measurement after the leaker was 98%, with a voltage of 7.0 volts, as shown in Figure 3. This would indicate that the defect grew at a rate of about 13% per month, although the growth rate would probably be non-linear in this range. There are also considerable uncertainties in the eddy-current measurements, but this is the best data available.

Another indication was found in tube 14-97 of C steam generator. This tube had been plugged at the 1991 outage. It showed indications as far back as 1988, and should have been plugged at an earlier outage. However, a "5 to 1" signal to noise category had been established at McGuire that allowed the tube to remain in service. This tube showed essentially the same signal in 1989 as it did

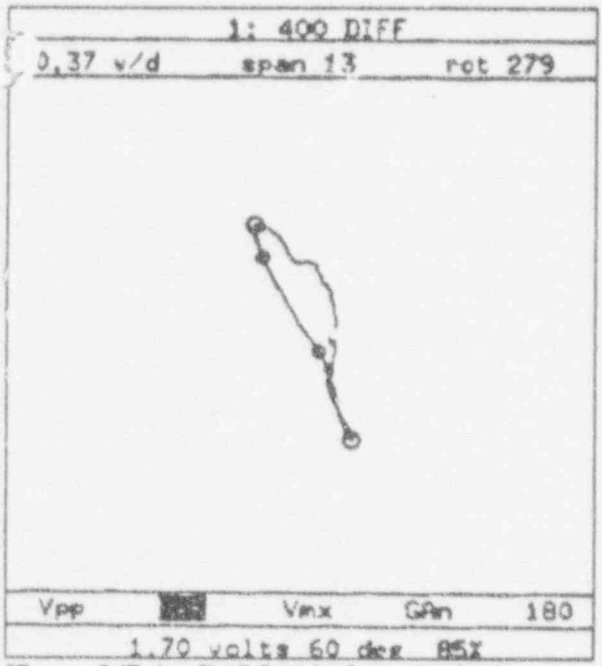

Figure 2 Tube R47C46 before the leak

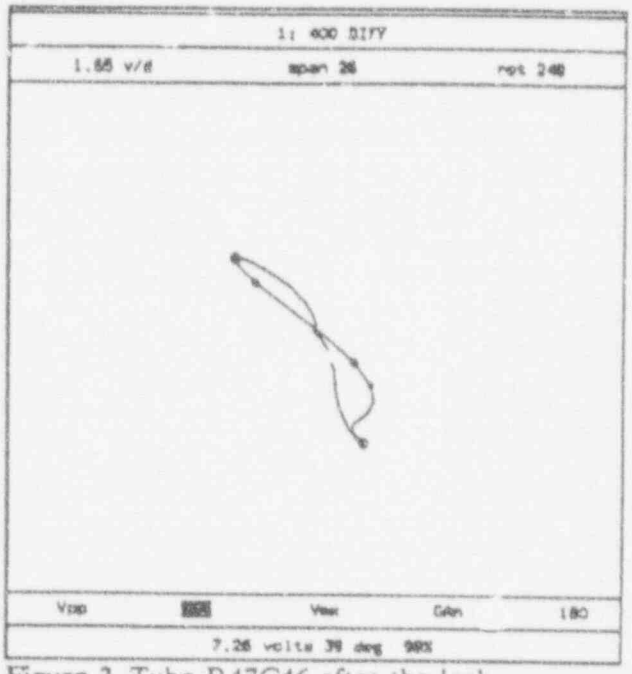

Figure 3. Tube R47C46 after the leak

in 1991, except the noise was lower (The category of "5 to 1" has been dropped by the utility). This indication shows very little growth, but it may be a different type of phenomenon.

Possible growth scenario One possible scenario is that a small groove that was too small to be easily seen by eddy currents was inscribed into the tube during manufacturing. An axial groove is visible on the scan of tube R47C46 between the 19th and 20th tube support plate that has the same circumferential location as the crack. However, I was told that this type of indication appears on many of the tubes. This groove accumulated deposits during operation and the chemical concentration of the deposits initiated the IGSCC. The time for the material to concentrate in the groove and to initiate the corrosion is on the order of several years, but the time required for the corrosion to propagate through the tube wall once it has started may be on the order of several months. However, at the time, this scenario is only speculation. The tube that ruptured in 1989 appeared to have a long scratch mark, and the tube that leaked in 1992 also had a long mark. The

initial leaking crack extended about 3 1/2 in. according to the ultrasonic scan, and several additional crack-like indications were found between the 15th and 14th tube support. Due to the location of both the 1989 tube rupture and the 1992 leak in the cold leg, the phenomenon is apparently not temperature related. It is also not generator related nor related to the heat of material.

Present inspection plan The utility conducted a review of the bobbin coil data according to a new revised procedure. Any defect like indications on the differential bobbin probe or vertical indications on the absolute channels require the further inspection with the motorized rotating pancake probe (MRPC). A total of 370 indications were found on 285 tubes in steam generator D. These tubes were all inspected with the MRPC. A total of 31 tubes were designated for plugging in steam generator D, with a designation of outer diameter indication, or ODI. Similar numbers of tubes are expected in the other three generators. According to the guidelines for the MRPC evaluation, there were no crack like indications in the tubes slated for plugging. When I left, these guidelines had not yet been written. The utility is using the Zetec 3-coil probe, which has a coil with an orientation to detect axial cracks, another coil to detect circumferential cracks, and the third coil is a normal pancake coil. This probe will work very well if the cracks are strictly axial or circumferential, but the metallography of the ruptured tube in 1989 showed a network of cracks with both orientations. Therefore, some small response may be obtained on the coil for circumferentially oriented cracks. Several tubes that I reviewed had long indications, some of which spanned the entire length between support plates.

An additional screening of all of the MEMs was conducted to determine if any of them had changed. Of the 285 tubes with the indications, only one showed definite signs of having changed. At the exit the utility asked if the screen for a change in signal would be adequate to detect all of the potential tubes with this type of defect. While this seems reasonable if the bobbin can detect this defect early enough, there is no guarantee of this. The additional MRPC scans seem prudent in view of the possible rapid growth rate of this phenomenon.

General observations The utility has its own equipment, does all of its own data acquisition and some of its own data analysis. Due to the expense and the overhead needed for training, the utility may not be using the latest equipment, techniques and software. The data analysis for 3 different Duke plants was being done in the same building. This would seem to leave some room for confusion.

Although the analysts were qualified on the particular plant that they are analyzing, the switching from one plant to another may cause confusion. This would be particularly true for the management personnel.

Recommendations:

1. The category of "5 to 1" has been dropped by the utility, as it should have been. However, this category has been used in all of the inspections at Duke Power's other plants. The category should be dropped for all of the plants and the data from the other plants should be re-evaluated without this category.

2. The Zetec three coil rotating pancake coil does a much better job at distinguishing between axial cracks and other types of degradation. It should be used for this inspection. However, since the tube rupture in 1989 showed a network of both circumferential and axial cracks, some response should be expected on the circumferential coil.

3. A formal written procedure should be developed for the MRPC to determine which tubes have cracks. Again, allowances should be made for the cracks going in both directions.

4. The utility needs a more formalized procedure for plugging so that defective tubes do not get left off of the plugging list.

5. The normal work day during an outage is 12 hours a day for both the data analyst and the supervisory personnel. A work day this long can lead to mistakes. Some consideration should be given to shortening the work day.

6. Some of the earlier scans appeared to have excessive probe wobble. For example, the scans of tube R47C46 of steam generator D that were made on September 30, 1991, were much noisier than those made on January 23, 1992. This is an industry wide problem which should be corrected at all of the power plants. A probe wear standard, similar to what is being proposed for the alternate plugging criteria, should be developed and automatically applied in the inspection.

7. Since the MRPC seems to be better at detecting this type of defect than the bobbin probe, an array probe with more pancake coils (16 for example) may give the sensitivity of the MRPC inspection with the speed of the bobbin coil inspection. This probe is not available at this time, but should be developed by the industry.

8. Due to the apparent fast growth rate of this phenomenon, a reduced operating cycle on the order of 6 months would be prudent.

Sincerely yours,

Caius V. Dodd

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