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DUKE POWER

June 1, 1992

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: McGuire Nuclear Station
Docket Nos. 50-369, -370
Inspection Report No. 50-369, -370/92-05

Gentlemen:

Please find attached Duke Power Company's revised response to Violation 369/92-05-01 for McGuire Nuclear Station. The revised response to the violation gives a chronology of events related to the McGuire Nuclear Station Steam Generators, incorporates new information acquired subsequent to the initial response and corrective actions taken. For completeness, the corrective actions are listed in the reason for violation and also listed in the corrective action section.

Should there be any questions concerning this matter, contact Larry Kunka at (704)875-4032.

Very truly yours,

T. C. McMeekin

Attachment

xc: Mr. S. D. Ebneter
Administrator, Region II
U.S. Nuclear Regulatory Commission

Mr. Tim Reed
U.S. Nuclear Regulatory Commission
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Mr. P. K. Van Doorn
NRC Resident Inspector
McGuire Nuclear Station

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McGUIRE NUCLEAR STATION
RESPONSE TO VIOLATION 369/92-05-01

VIOLATION 369/92-05-01

Technical specifications 4.4.5.3 and 4.4.5.4 require that steam generator tubes with wall degradation equal to or greater than 40 percent of nominal wall thickness be plugged.

Contrary to the above, on October 1, 1991, tube R47-C46 in steam generator D, was examined and analyzed as having a potential defect of approximately 85 percent through wall depth, but was returned to service on December 8, 1991. The subject tube developed a through wall leak and caused the plant to shut down on January 16, 1992.

This is a Severity Level IV violation (Supplement I).

Response to Violation 369/92-05-01

Reason for violation

Introduction

Provided below is a chronology of significant events related to the occurrence of freespan cracking in the cold leg (CL) of the McGuire steam generators (SG). This chronology details the increasing level of understanding of the phenomena and its impact on unit operation from the tube rupture in March, 1989 through May, 1992. While the cause(s) of these failures is not completely understood, much additional information concerning the defects is now available. The understanding and detection capabilities continue to advance with improvements in inspection methodology and technical expertise. This chronology addresses defect geometry, propagation rates and location in the SGs. Defect leak and burst characteristics and Eddy Current Test (ECT) responses are discussed. This information has been developed through extensive ECT and enhanced data analysis (which involved three revisions to the evaluation guidelines, each more restrictive than the previous), laboratory analysis of pulled tubes, draft Regulatory Guide 1.121 analysis and leak/burst testing results.

The standard code examination used for SG tubing consists of a bobbin coil examination. The ASME code requires that the inspection technique be capable of distinguishing a 20 percent throught wall flaw from probe motion, and that all indications equaling 20 percent through the outer tube wall be reported. The calibration standard is required to contain four 0.1875 inch diameter flat bottom holes spaced 90 degrees around the tube.

The 20 percent calibration flaw will typically produce a signal with an amplitude of 2.8 - 4.7 volts on the 400 and 130 Khz differential channels respectively. Common values for the very small indication being reported with the stringent analysis guidelines are in the range of 0.10 - 0.20 volts on the 400 and 130 Khz channels.

A supplementary Motorized Rotating Pancake Coil (MRPC) examination is also used on many of the indications detected by bobbin coil to further characterize the degradation morphology. The MRPC probe accomplishes this by concentrating the Eddy Current field by virtue of its small coil. A consequence of the enhanced characterization is a lower sensitivity to outside diameter (OD) wall degradation than to inside diameter (ID) wall degradation. The calibration voltage is adjusted to equal 10 volts on a 100 percent through wall EDM notch approximately 0.006 inches wide. The EDM 20 percent OD calibration notch measures 200 times smaller (at 0.05 volts) than the 100 percent notch. The tube "noise" or potential masking signal can measure 3 times the response of the 20 percent OD signal even in "clean" calibration standard tubing. In-generator actual tube noise runs much larger than this. The ECT data is currently being scanned at or below the level of the 20 percent OD notch.

Initial Tube Rupture

In January, 1989, a small leak developed in SG 1B. The leak rate increased from the lower limits of detection to ~16 gpd. On March 7, 1989, Unit 1 experienced a SG tube rupture resulting in an approximate 540 gpm leak. The unit was removed from service with no complications. Post rupture testing identified the failed tube as 18-25. The tube exhibited an axial crack, approximately 3.25 inches in length. The crack extended 0.25 inches above the first tube support plate (TSP) on the CL through the TSP and terminated 2.25 inches below the TSP. Tube 18-25 had not been tested since the preservice inspection was performed in 1978.

Prior to the rupture of 18-25, an inservice ECT plan consisted of full length bobbin coil examination of periphery tubes, tubes on which calls had been made previously, and a sampling of tubes chosen at random for a total of 20 percent of the tubes.

Sections of tubes 18-25, 19-25, and 13-34 were removed from the SG 1B. Tube 19-25 was removed from SG 1B to gain access to tube 18-25. Tube 13-34 was removed from SG 1B for ECT indications similar to those observed in tube 18-25. Tubes 18-25 and 13-34 were subjected to extensive metallurgical analysis. The metallurgical report indicated that the rupture resulted from an axial crack ~ 3

inches long in the area below the first TSP on the CL of the SG. The crack itself was located in a long axial groove, 40 mils wide by 1 mil deep. The groove was believed to be the result of the SG manufacturing or the tube installation process. Numerous other small cracks were also associated with the groove. Analysis of tube 13-34 revealed no indications of cracking. Based on this information, it was concluded that the failure was an isolated event resulting from Intergranular Stress Corrosion Cracking (IGSCC). It was further concluded that the groove was integral in the formation of the crack.

With this information in hand, Duke expanded its inservice ECT plan to include a 100 percent, full length bobbin coil inspection of all SG tubes. Tubes exhibiting significant bobbin coil indications would be further analyzed using Rotating Pancake Coil (RPC). This inspection was completed prior to the restart of Unit 1. The analysis of the acquired ECT data was performed with particular attention to long defects. Based on the expanded inspection, a number of tubes with long axial indications, characterized as installation or manufacturing defects were removed from service.

The unit was returned to service based on the following:

- In concurrence with the metallurgical analysis, the failure was believed to be an isolated event resulting from IGSCC in conjunction with a manufacturing defect.

- Due to of the expanded inservice inspection consisting of 100 percent bobbin coil examination of all SG tubes and special interest tubes receiving inspection by RPC, all tubes with similar installation or manufacturing type indications were removed from service.

- The expanded inspection program of all SG tubes would detect any future cracking, should it occur.

- A growth rate determination of 0.7 mils/month was extrapolated based on laboratory and inspection data from the hot leg and corrected for temperature to the cold leg; and, it was concluded that the unit could run safely for a complete refueling cycle.

The expanded inservice inspection plan and the decisions resulting from this event represented the best understanding of the morphology, origin, and rates of propagation of the indications at that time. These decisions were based on extensive ECT and laboratory analysis. In 1990, the inspection was expanded to include examination of the hot leg (HL) tube sheet using Rotating Pancake Coil (RPC). RPC was performed on selected special interest tubes. Both McGuire units operated without incidence of leakage

for the next 34 months. From March, 1989 through December, 1991, all SG tubes in both McGuire units were examined full length 3 times. One free span indication similar to the indication on tube 18-25 was noted on tube 14-97 in SG 1C in December, 1991 and was removed from service.

STEAM GENERATOR 1D, TUBE 47-46 LEAK - JANUARY, 1992

In December, 1991, a leak was detected in SG 1D. From January 8 through 15, 1992, calculations indicated the leak increased from ~8.3 to ~ 20 gpd. On the morning of January 16, accelerated chemistry sampling and leak rate calculations indicated the leak had increased to ~ 22 gpd. Sampling at 1747 hours and 1835 hours on the same date, revealed leak rates of 250 and 220 gpd respectively. At 1912 on January 16, 1992, Operations personnel commenced an orderly shutdown of McGuire Unit 1. The unit entered Mode 5 (Cold Shutdown) at 0552 on January 18, 1992.

During the Unit 1 End of Cycle 7 (EOC7) refueling outage, the primary reviewer reviewing eddy current bobbin coil data for SG 1D, flagged an indication on tube 47-46. The same indication was independently flagged by a secondary reviewer. The primary reviewer classified the indication as signal to noise (S/N) and as a manufacturing burnishing mark (MBM). The primary reviewer classified the indication as an MBM based on the characteristics of the signal and his opinion that the phase angle was not a true representation of the depth of the indication.

A classification of S/N means there is an indication of degradation, but the signal to noise ratio is too low to be accurately sized as to tube through wall depth (TWD). The characterization as an MBM implies that there is present an imperfection in the tube related to the tube buffing or polishing during the manufacturing process.

The secondary reviewer classified the indication as 85 percent through wall depth. As a result of the differing classifications, the indication was sent for evaluation by a resolution team. The resolution team misclassified the indication as an MBM. This call was an error, and not in compliance with the analysis guidelines in place during this inspection ("Eddy Current Analysis Guidelines, McGuire Nuclear Station, Unit 1, Rev. 1 dated 7/10/91"). The appropriate call for this indication, with a S/N ratio greater than 8/1, was 85% TWD, as identified by the secondary reviewer.

The analysis guidelines state "For indications with a S/N ratio less than or equal to 5, only the location and type of flaw (if possible) shall be recorded with an accompanying note of "S/N" in the % TW column.

For indications with a S/N ratio greater than 5, the location, type (if appropriate), and % TW shall be recorded."

Further, they stated "The S/N requirements specified may be superseded by the data analyst and the indication assigned a % TWD on a "best effort basis" if steam generator history, flaw growth history, expected flaw type or geometry, multiple flaws, flaw signal amplitude, or any other pertinent information warrants this action."

These statements allow flexibility to the analyst to use his/her judgement in making a call. To rectify this, suggested S/N limits have been deleted from the analysis guidelines.

When the Support Engineer received the tube results list from the data analysts, he requested additional examination of the indication using the motorized rotating pancake coil (MRPC) test technique. The MRPC data provides the shape of an indication. The MRPC data was evaluated by primary, secondary and resolution analysts and recorded as an outside diameter indication (ODI). These results were sent to the Support Engineer for disposition. The information received on the indication did not receive the appropriate evaluation by the Support Engineer and was therefore not identified for plugging.

Since the problem was believed to be one of a misclassified indication all indications were reviewed to ensure proper classification. Those indications classified as MBM's were removed from service in the A, B, and C SG's. Those classified as MBM's in the SG 1D were being inspected by MRPC to expand the data base.

New bobbin coil data acquired during the January, 1992 outage revealed another indication with an amplitude of 0.46 volts and indeterminate depth at the 15th TSP + 5.81 inches on tube 47-46. This indication was inspected by MRPC and was identified as crack like. This indication was not noted in the original September, 1991 data analysis. A subsequent expert review of the September, 1991 eddy current data revealed the presence of this indication.

Based on the unnoted indications, a complete review of all Unit 1 ECT bobbin data for all SG's collected during the September, 1991 outage was initiated using an enhanced indication identification system and guidelines. The unnoted indication in tube 47-46 (0.46 volts) was used to develop the new guidelines. The guideline enhancements included the following:

1. Emphasis on the detection of freespan indications

2. No minimum voltage threshold

3. Report any and all indications of degradation regardless of depth

4. Emphasis on rolling the primary differential channel

5. Investigation of positive responses on the 100 kHz absolute vertical strip chart

6. Differential responses within specified defect plane

7. Absolute responses within specified defect plane

In addition, analyst were trained and tested specifically on the new guidelines and the detection of freespan cracks relative to the best known information at the time.

INFORMATION FROM ECT

An average of 245 tubes per SG were examined with MRPC. Based on the evaluation of this testing, an average of 44 tubes per SG (176 total) were removed from service. These tubes were removed from service because they exhibited indications classified as MBM as noted above, or MRPC detected crack like indications, or that the indications had grown when compared with previous bobbin coil data. Expert review indicates that none of the tubes removed from service were similar to the indication noted on tube 18-25 and 47-46.

A Human Performance Enhancement System (HPES) investigation into this event has identified factors such as extended work hours and fatigue of the data analysts that may have contributed to this misclassification and missed defect. In response to this finding, the following policy changes were effected:

- The work schedule of the ECT analysts has been reduced from six days at 12 hours per day to six days at 10 hours.

- A point contact has been established to interface between the SG team and ECT analysts to ensure a timely and accurate transfer of information concerning ECT inspection need, progress of inspection and scheduling concerns

Additionally, a process study will be initiated to better define the responsibilities of the Lead Data Analyst and Team members and enhance the overall process for future outages.

The only outstanding issue at that time, was the growth rate of the defects. Tube 47-46 had been ECT at the beginning of Cycle 7.

Analysis of the growth rate on this and other defects showed growth rates from .4 to ~ 3 mils/month, with a most probable growth rate of 1 - 1.5 mils/month. An issue to be addressed prior to restart was providing assurance that the unit could be operated safely until the next ECT inspection. The analysis of this problem depends on the size of the postulated defect left in service (i.e. the postulated data was assumed to be 50 percent through wall), the growth rate of the defect, and the draft Regulatory Guide 1.121 criteria for normal pressure and accident conditions. A preliminary analysis, using conservative assumptions, indicated that the unit could be operated safely for several months without exceeding draft Regulatory Guide 1.121 criteria. The unit was returned to service with a commitment to meet with the NRC in approximately three months to share the results of the final analysis. The results of the work performed on McGuire Unit 2 would also be available for discussion at that meeting.

McGUIRE UNIT 2 INFORMATION

Unit 2 was in a refueling outage prior to the tube leak outage on Unit 1 in January, 1992. The data evaluation had begun prior to the development of the enhanced guidelines. The analysis of the data to original guidelines had identified freespan indications in tubes 5-29, 18-5, and 18-10. As a result of the unnoted indication on Unit 1 and the freespan indications found in Unit 2, all Unit 2 data was reevaluated to the enhanced analysis criteria developed for Unit 1. An average of 362 tubes per SG were examined with MRPC. Based on the evaluation of this testing, an average of 27 tubes per SG (106 total) were removed from service. Two additional freespan crack like indications were noted.

Tubes 18-5, 18-10, and 5-29 had been inspected by MRPC and freespan crack like indications were confirmed. These three tubes with crack like indications were removed for metallurgical examination. The examination focused on the following areas:

- Verification or enhancement of the ECT detection limit.
- Obtaining burst pressures for the CL free span type defects.
- Obtaining leak rates for the CL free span type defects.
- Further investigation of the phenomenon to identify the origin of the cracks.

The examination of the tubes revealed the following information:

- Tube 5-29 exhibited a single defect of 62 percent average through wall and a length of 0.5 inches. The defect burst at 4200 psi. This defect was located in a small area of surface damage. Subsequent review questioned the validity of the burst pressure results (see burst pressure discussion below). The defect had been characterized by the inspection and analysis program.

- Tube 18-10 also exhibited a single defect 73 percent average through wall and a length of 0.5 inches. The defect burst at 2000 psi (see burst pressure discussion below). Again, the defect was located in a small area of surface damage. This indication had been detected and the tube identified for removal from service.

- Tube 18-5 had an axial groove, 117 inches in length. The indication was very similar to the indication on tube 18-25 which was removed from Unit 1 in 1989. There were numerous small cracks in this groove. Two major cracks were also noted in the groove:

  a. Crack 1 was located at TSP 21 +2.2 inches. This crack was 1.1 inches in length, with an average through wall depth of 54 percent and burst at 4800 psi (see burst pressure discussion below). The defect had not been detected by the bobbin ECT field evaluation.

  b. Crack 2 was located at TSP 15 -1.1 and was 1.4 inches long, with an average through wall depth of 72 percent. Crack 2 burst at 550 psi; however the burst pressure results were subsequently invalidated (see burst pressure discussion below). This crack was noted in the original data analysis.

The information with the most significant impact on the operation of the units was the lower than expected burst pressures and the presence of an undetected defect on tube 18-5. These are discussed separately.

Burst Pressure

A total of five defects were burst tested. The burst pressures were compared to calculated pressure for this defect geometry and

to large amounts of industry data. The industry data included manufactured and actual cracks. Of the five defects tested, two burst at pressures at or near the expected burst pressures. The remaining three burst at pressures significantly below those expected based on the calculations and industry data. The initial burst test results were subsequently invalidated.

It was felt that the low burst pressures resulted from an unknown factor in the test procedure. This theory was validated by preforming burst tests on specimens with defect geometries similar to the actual defects. There was one notable exception to the validation. The tests indicated that the burst pressure for a long, shallow defect with a deep center section, was significantly lower than calculated values or the values supplied from the industry data base. This information placed a significant limit on the allowable unit operation cycle length based on draft Regulatory Guide 1.121 criteria.

Undetected Defect

A defect was discovered on tube 18-5 which had not been detected by field ECT. This defect was 1.1 inches in length with an average depth of 54 percent through wall. The ECT signal amplitude of this indication was in the magnitude of 0.2 volts. A review of the signal by ECT experts, indicated that the signal could have been identified during the field analysis. To confirm this supposition, a blind test was conducted. The results showed that with the guidelines in place at the time the field ECT was analyzed, the defect was noted only 50 percent of the time. This indicated to a lack of consistency in the bobbin analysis. The guidelines were again modified to incorporate the lesson learned and improve the consistency of the analysis process. The changes to the guidelines were as follows:

1. Addition of a data screening section to specify how the data should be screened
2. Differential responses without specified defect plane
3. Absolute responses without specified defect plane

Additional training was conducted to emphasize the metallurgical results and the eddy current responses from the pulled tubes.

SHUTDOWN OF McGUIRE UNIT 1

Based on the burst pressure test results and the undetected indication with an average through wall depth of 54 percent, it was decided that another review of the Unit 1 ECT data collected in September, 1991 should be conducted utilizing the signal characteristics obtained from the undetected indication. The guidelines were again revised as noted above to incorporate lessons learned. The purpose of this review was to determine if any indications might exist in the steam generator that were similar to the unnoted indication on Unit 2, tube 18-5. This review began on April 27, 1992. Two tubes with indications similar to the undetected indication on tube 18-5 were identified and on May 4, 1992, Unit 1 was removed from service to validate these indications and perform additional inspections.

Unit 2 remained in service at this time. The continued service of Unit 2 was based on the assumption that if a missed indication similar to the one in tube 18-5 existed and applying average reasonable growth rates, it was determined that the unit could safely operate for four months prior to exceeding draft Regulatory Guide 1.121 criteria. It was decided to remove Unit 2 from service on or about May 22, 1992 to conduct similar ECT and analysis. The outage plans and scope for both McGuire units are documented in a letter from T.C. McMeekin to the NRC dated May 8, 1992.

Additional systematic improvements have been incorporated into the eddy current process as follows:

- Incorporated the use of a computerized scanning system to add further credibility to the calls made by the data analysts.
- A random selection of ECT data will be reviewed to add assurance that no ECT signal are missed.
- Utilize a larger fill factor bobbin coil probe.

Corrective steps taken and results achieved

SUMMARY

Throughout this entire series of events, there has only been one instance of a tube defect that was not properly removed from service based upon the guidance and state of the art knowledge in effect at the time. These corrective actions are intended not only to eliminate those types of errors, but more significantly, have put in place increasingly improved, more stringent criteria, processes and training to advance our capability to consistently detect these freespan, tight cracks previously unseen in the nuclear industry.

Corrective steps taken in response to the leak in tube 47-46

Corrective steps 1 through 6 were completed prior to the end of the Unit 2 EOC7 outage. Corrective steps 7 through 12 were completed after the Unit 2 startup.

1. Operations Control Room personnel commenced an orderly shutdown of Unit 1 on January 16, 1992.

2. The leaking tube was identified by Maintenance personnel as being in S/G 1D and was removed from service.

3. All of the bobbin coil eddy current data from Unit 1 End of Cycle (ECC) 7 outage was reevaluated using a revised conservative criteria which included the following:

    1. Emphasis on the detection of freespan indications

    2. No minimum voltage threshold

    3. Report any and all indications of degradation regardless of depth

    4. Emphasis on scrolling the primary differential channel

    5. Investigation of positive responses on the 100 kHz absolute vertical strip chart

    6. Differential responses within specified defect plane

    7. Absolute responses within specified defect plane.

4. Based on the new criteria, 176 tubes were removed from service. These tubes were removed from service because they were classified as MBM's .

5. Technical Specification 3.4.6.2 (c), primary to secondary leakage for Unit 1 for the remainder of cycle 8 will be administratively limited to 50 gpd/SG, with Mode 3 being reached within 12 hours.

6. The revised conservative eddy current criteria was used to analyze the bobbin coil data acquired during the Unit 2 EOC 7 inspections.

7. The eddy current analysis guidelines were revised to delete the "S/N" limits of 5 to 1 that may lead to a lack of conservatism in the eddy current results. This will require

that a signal influenced by noise will receive further evaluation or tests.

8. The eddy current guidelines were revised to clarify the use of "MBM" and other discontinuity codes.

9. Administrative controls were developed to address the manner in which information on tubes is conveyed to Engineering for tube disposition.

10. Administrative controls were developed to address Engineering's role and authority in the tube disposition process.

11. A Human Performance Enhancement System evaluation has been performed to address the human factors affecting this event. The following changes have already been incorporated:

    A point contact has been established to interface between the SG team and ECT analysts to ensure a timely and accurate transfer of information concerning ECT inspection need, progress of inspection and scheduling concerns.

    The work schedule of the ECT analysts and team members has been reduced from six 12 hour days to six 10 hour days.

12. Eddy current analysis management personnel have conducted a review of eddy current procedures and made enhancements as necessary.

Corrective steps taken in response to the undetected defect on tube 18-5

1. The criteria were again modified to incorporate the lessons learned and improve the consistency of the analysis process.

2. Additional training was conducted to emphasize the metallurgical results and the eddy current responses from the pulled tubes.

3. Technical Specification 3.4.6.2 (c), primary to secondary leakage for both units for the remainder of cycle 8 will be administratively limited to 50 gpd/S/G, with Mode 3 being reached within 12 hours.

Corrective steps to be taken to avoid further violations

We consider the previously described corrective actions adequate to prevent future violations of this nature. However, to further evaluate and seek ways to optimize our process, we will perform the following:

A process study will be performed to enhance the overall process for future outages.

Date when full compliance will be achieved

McGuire is currently in full compliance with our Technical Specifications. All corrective actions are complete except for the process study and it will be completed by September 1, 1992.