



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
REGION II  
101 MARIETTA STREET, N.W.  
ATLANTA, GEORGIA 30323

Report Nos.: 50-369/92-14 and 50-370/92-14

Licensee: Duke Power Company  
422 South Church Street  
Charlotte, NC 28242

Docket Nos.: 50-369 and 50-370

License Nos.: NPF-9 and NPF-17

Facility Name: McGuire 1 and 2

Inspection Conducted: May 11-15, 26-29 and June 9-12, 1992

Inspector: *N. Economos*  
N. Economos

*02/01/92*  
Date Signed

Approved by: *J. J. Blake*  
J. J. Blake, Chief  
Materials and Processes Section  
Engineering Branch  
Division of Reactor Safety

*7/1/92*  
Date Signed

SUMMARY

Scope:

This announced inspection was conducted in order to oversee eddy current (EC) examination of Unit 1 steam generator (S/G) tubes and assure that data analysis and resolution guidelines have adequate conservatism to help identify all crack like indications and thereby remove suspect tubes from service.

Results:

The licensee has demonstrated significant strength in engineering management and technical support. Cognizant engineers and technicians were well trained, knowledgeable and communicated well with line supervisors and technical personnel. Analysis guidelines were revised so that all suspect bobbin indications were examined with motorized rotating pancake coil probes and the results were subsequently analyzed and evaluated. Industry technical experts participated in the evaluation and disposition process. Recording levels of indications were lowered to the threshold of detectability. Tubes plugged in Unit 1, during this

outage were as follows:

S/G"A"-80, S/G"B"-20, S/G"C"-36 and S/G"D"-46.

Preliminary results of metallurgical and nondestructive examinations conducted on tubes 3-92 and 14-94 indicated no evidence of significant indications on the sections examined. There was no evidence of corrosion cracking on the post burst fracture surfaces including gouge edges and OD surfaces. Burst test results showed mechanical properties were consistent with material type (Inconel-600) and thickness.

Within the areas inspected violations or deviations were not identified.

## REPORT DETAILS

### 1. Persons Contacted

#### Licensee Employees

- J. Baumann, Supervisor Level III Eddy Current Examiner
- F. Bulgin, Technical Services, NDE Supervisor
- \*C. B. Cheezem, Manager, NDE General Services Department
- \*T. Cook, Generation Services Manager
- G. Gilbert, Safety Assurance Manager
- \*P. Herran, Manager Engineering
- \*T. McConnel, Station Manager
- \*T. McMeekin, Vice President, McGuire Nuclear Station
- \*D. Mayes, Maintenance Engineer, Steam Generators General Offices
- \*K. Mullen, Compliance Associate Engineer
- \*R. Sharpe, Regulatory Compliance Manager

Other licensee employees contacted during this inspection included technical support, QA, and administrative personnel.

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#### Other Organizations

Westinghouse Electric Corporation: (W)

Dr. W. R. Junker, Fellow Scientist, Material Reliability

Electric Power Research Institute (EPRI)

#### NRC Resident Inspectors

- \*K. VanDoorn, Senior Resident Inspector
- \*T. Cooper, Resident Inspector

\*Attended exit interview

### 2. Eddy Current Examination of S/G Tubes in Response to Undetected Cracklike Indications During Previous Outage, Units 1 and 2 (73753)

On January 15, 1992, Unit 1 was shut down in response to a leak in S/G D which was subsequently attributed to tube 47-46. During the review of previous E/C examinations conducted on this tube it was determined that the root cause for this problem/leak was related to a miscall by analysts.

Because of the miscall the tube was returned to service with a code rejectable crack indication; for more details on this matter see RII Report 369,370/92-05. At the time that this leak was identified, Unit 2 was in a refueling outage and along with other activities, S/G tubes were undergoing E/C examination as part of the ISI program. Analysis of data from that inspection revealed free span crack like indications in tubes 5-29, 18-5 and 18-10 of S/G"C" cold leg side. Because of the miscall in Unit 1 and the above mentioned freespan indications found in Unit 2, all Unit 2 data was subsequently reevaluated to enhanced analysis criteria. The three aforementioned tubes were removed for analysis. The analysis included a metallurgical investigation, verification of EC detection limit and burst pressure tests for tube sections with free span crack like defects. Results of this analysis disclosed the presence of two significant cracks located in an axial groove of tube 18-5. One of the two cracks was approximately 1.1 inches long with an average through wall depth (TWD) of 54%, while the other was approximately 1.4 inches long with an average TWD of 72%. Because of unfavorable burst pressure test results on the aforementioned tube sections, and the undetected indication in tube 18-5, the licensee decided to conduct a re-review of Unit 1 EC data collected during the September 1991 outage. Analysis Guidelines were revised to provide increased conservatism and to incorporate lessons learned information from tube 18-5 above. The re-review began on April 27, 1992, and resulted in identifying two tubes, 3-92 and 14-94 in S/G"A" cold leg, with free span indications similar to that which went undetected in tube 18-5. This finding prompted the licensee to shutdown Unit 1, in order to validate these indications and to conduct a re-examination of tubes in all four S/G(s) of Unit-1. Unit-1 was shutdown for this purpose on May 4, 1992. By memorandum dated May 8, 1992, DPCo confirmed plans for eddy current inspection of both McGuire Units. These inspection plans were as follows:

#### Unit 1

- a. Bobbin coil inspection and analysis would be performed on the cold legs of each S/G and the hot leg of S/G "A". The hot leg of S/G "A" was included because Unit 1 had a small leak in the 'A' Steam Generator prior to shutdown.
- b. Special eddy current inspection and/or analysis would be performed for all indications that were identified during the bobbin coil inspection.
- c. Up to six tubes would be selected to be pulled for further test and inspections.

- d. A variety of inspection data would be acquired prior to the tube pulls for later correlation/validation with the lab analysis.
- e. All tubes meeting DPCo plugging criteria would be removed from service and the unit would be returned to service.

#### Unit 2

- a. Inspections and analysis on all cold leg tubes would be performed incorporating any lessons learned from Unit 1. As a minimum, this would include bobbin coil on all cold leg tubes. Special eddy current inspection and/or analysis would be performed for all indications that were identified during the bobbin coil inspection as a minimum.
- b. All tubes meeting DPCo plugging criteria would be removed from service and the unit would be returned to service.
- c. The Technical Specification 3.4.6.2(c) primary to secondary leakage for both units had previously been administratively limited during the remainder of Cycle 8 to 50 gpd/S/G; with Mode 3 reached within 12 hours. This was previously committed for Unit 1 in a February 7, 1992 letter but was implemented for both units at that time. This letter documented DPCo's commitment to apply this more conservative leakage criteria to Unit 2.

On May 11, 1992, an inspector arrived at the McGuire site and ascertained through discussions and observation that the leak in the hot leg of S/G "A" had been attributed to a leaky sleeve in tube R16-C106. Preparations for data acquisition were in progress which included installation of nozzle dams and manipulators for ECT equipment. To improve on the lack of consistency in the analysis of bobbing data, which was mostly responsible for the failure to detect the crack indication in tube 18-5, the licensee further revised the Analysis Guidelines. This revision dated May 8, 1992, incorporated lessons learned which resulted in the following changes:

- a. Addition of a data screening section to specify how data should be screened,
- b. Differential and absolute responses without specified defect plane.

Additional training was provided to analysts and supervisors emphasizing the metallurgical investigation results from tube 18-5 and eddy current responses from previously pulled tubes. Other programmatic improvements added to this inspection effort included:

- Use of a computerized data scanning (CDS) system to add further credibility to calls made by data analysts. This system screened out signals of interest from raw multifrequency EC data. The system has the demonstrated capability to detect signals below threshold levels.
- Review a random selection of EC data thereby adding assurance that EC signals were not missed.
- Utilization a larger of fill factor bobbin coil probe capable of detecting indications  $\geq 20\%$  through wall depth.

Earlier revisions to procedures and Analysis Guidelines made in response to the leak in tube 47-46 were addressed in Report 50-369, -370/9-05.

Significant highlights of Analysis Guidelines Revision 2, implemented during this EC inspection effort were as follows:

#### Date Screening:

- The 400 Khz differential channel was viewed as the primary reference frequency. All data acquired was initially analyzed at this frequency or channel No. 3.
- Data was scrolled on the 100 Khz differential frequency or channel No. 5.
- Any absolute channel positive drift signal observed by analysis, was researched and reported according to specified procedure.

#### Reporting Criteria:

- All signals indicative of degradation, regardless of depth and with no minimum voltage threshold were to be reported.
- Any indication detected using a differential channel that occurred in the defect plane and was confirmed to be in the defect plane of another differential channel, was to be reported.
- Any indication detected using an absolute channel, that did not exhibit a clear transition on a differential channel, could be reported using channel 6. If the indication detected occurred in the defect plane of channel 6 (130 khz ABS) and fell in the defect plane of channel 4 (400 Khz ABS), was to be reported using the signal on channel 6 (100 Khz ABS).

- ° Special attention was given to indications at the hot leg tube support plates, where any indication of intergranular corrosion or outside diameter stress corrosion cracking was to be reported regardless of the voltage or indicated depth.

#### Recording Criteria

- ° All freespan indications were to be recorded with the 200 KHz differential channel as practical.
- ° All indications within the tube support plate intersections were to be recorded using specified channels, depending on flaw classification.
- ° All indications found in the tubesheet or at the top of the tubesheet/roll transition area were to be reported using specified channels and through wall depth assessment

Other indications with recording/reporting requirements included dents, skip rolls, overexpansion and over-rolls.

In addition to the Analysis Guidelines already discussed, the inspector reviewed, for content and technical adequacy, several procedures used for data acquisition. The most significant of these were as follows:

- ° NDE-701 Rev. 1 Multifrequency Eddy Current Examination of S/G Tubing at McGuire, Catawba and Oconee Nuclear Stations Only.

This procedure was written to comply with applicable sections of ASME Code Section XI 1980 Edition through Winter 1980 Addenda and, RG 1.83 July 1975, and Code Case N-401.

- ° NDE-702 Rev. 0 Nondestructive Examination Program.
- ° NDE-707 Rev. 1 Multifrequency Eddy Current Examination of Nonferrous Tubing Using a Motorized Rotating Pancake Coil (MRPC).

In addition the inspector reviewed, personnel certification records for approximately twenty-five analysts and/or examiners; equipment calibration records and calibration standards quality records. Data acquisition was observed on all four S/G(s), which provided an opportunity to observe in-line calibration probe position verification, signal quality and verification of scanning speed. Daily field logs were also reviewed at this time. Through

these document reviews, work observations and discussions with cognizant personnel the inspector also ascertained the following pertinent examination parameters. These are included to provide a standard for comparison between code established acceptance criteria and those employed by DPCo for this inspection. The 20% OD calibration flaw in the code calibration standard, equals approximately 0.009" in depth and produced a signal with an amplitude of about 2.8-4.7 volts on the 400 Khz and the 130 Khz differential channels respectively. Indications which were identified for further analysis during this outage exhibited signals with amplitudes in the range of 0.10 to 0.20 volts on the 400 Khz and 130 Khz channels. In some cases where analysts determined that bobbin coil signals required further evaluation, a supplementary MRPC examination was performed. The calibration standard used for this examination contained a very narrow, through wall EDM notch approximately 0.006 inches wide, calibrated to produced a signal with an amplitude of approximately 10 volts. By comparison, the 20% OD calibration notch on this standard, produced a signal with an amplitude of approximately 0.05 volts or 200 times smaller than the 100% percent through wall notch mentioned above.

At the same time, tube/material signal (noise) can generate up to three (3) times the response of the 20% OD notch signal on the calibration standard and significantly higher in S/G tubing. During this outage, eddy current data was being scanned for indications with signals having voltage amplitude  $\leq$  than those produced by the 20% OD notch or within the material noise level. Other measures taken to increase the level of assurance that suspect indications were not being missed or miscalled by analysts, included a spot audit program providing for a 2% random sample review of bobbin coil examinations. This audit was performed during each shift by lead analysts. Tubes plugged in Unit 1 during this outage are summarized in the following table.

#### Unit 1 Steam Generators

<u>Condition</u>	<u>"A"</u>	<u>"B"</u>	<u>"C"</u>	<u>"D"</u>	<u>Total</u>
Volumetric > 40% TW	22	7	8	17	54
Dents	37	5	14	20	76
Free Span Axial Crack Like	16	6	13	8	73



		7			
Others	5	2	1	1	9
Plugged for miscellaneous reasons					

Tubes Plugged per Steam Generator

80	20	36	46	182
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The following tabulation summarizes the number of tubes available for plugging before Unit 1 reaches the 10% plugging limit.

Unit 1 Steam Generators

<u>Plugged Tubes</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
Before Outage	182	107	112	126
Plugged during outage	<u>80</u>	<u>20</u>	<u>36</u>	<u>46</u>
Balance	102	87	76	80

The relatively small number of tubes remaining before the 10% plugging limit is reached has prompted the licensee to explore the possibility of raising the limit from 10% to 15%. As stated earlier, the scope of the E/C inspection during this outage called for a bobbin examination of all tubes in the cold leg (CL), in all four S/G(s) and in the hot leg (HL), of S/G"A". The latter was performed in response to the leaker in the HL of S/G"A", detected prior to shutdown and subsequently identified as (16-106).

Following analysis and evaluation of bobbin indications the following tubes were examined with MRPC probes.

Unit 1 S/G Tube MRPC Examination

	"A"	"B"	"C"	"D"
Cold Leg	557	306	394	520
Hot Leg	458	—	—	—

The licensee decided against proceeding with EC examination of the HL(s) of S/G(s) B, C and D when the MRPC examination in S/G"A" HL, revealed no significant indications. Tubes earmarked for plugging following disposition were discussed earlier in this report.

°Preliminary Examination Results on pulled Tubes  
 Tubes pulled for metallurgical, destructive and

nondestructive examination during this outage were as follows:

Unit 1

S/G"D" Cold Leg

- |       |  |
|-------|--|
| 47-46 | Tube with through wall crack responsible for plant shutdown in January 1992. |
| 47-47 | Bobbin indications pulled for further investigation of noise from ID signals |
| 49-62 | Previously plugged, selected due to ducts and other OD generated signals.    |
| 9-56  | pluggable indication axial freespan.   |

S/G"A" Cold Leg

- |       |  |
|-------|--|
| 3-92  | Tubes with indications similar to undetected indication in 18-5.           |
| 14-94 | Caused plant to shut down for verification and additional EC examinations. |

S/G Tubes

3-92 and 14-94, Field Inspection and Laboratory Examinations

As discussed earlier in this report, the EC data of the subject tubes obtained during the September 1991 outage, were re-reviewed because of an undetected indication in Unit 2 S/G tube 18-5 and some unsatisfactory burst test results on this tube, a discussion of which is not within the scope of this report. The EC data rereview was performed with analysis guidelines that had been revised to incorporate lessons learned from the missed indication in the 18-5. The licensee's review of data from present and previous EC examinations with bobbin coil showed the following:

- |                   |   |
|-------------------|---|
| Tube 14-94 S/G"A" | Indication exhibited some growth between 1990 to 1991 and some phase rotation. During the present outage, analysis of bobbin data showed evidence of a crack like indication with a signal amplitude within the threshold of detection. The technician's expert review reported no obvious evidence of growth, MRPC data suggested the indication was volumetric in nature. |
| Tube 3-92 S/G"A"  | The indication in this tube was not called by   |

the primary analyst of bobbin coil data; the indication appears to be below the threshold of the computerized data analysis system. Analysis of the signal during the current inspection indicated some evidence of growth in amplitude.

Both tubes were examined with the bobbin coil, the MRPC and with a nonmagnetic biased bobbin coil to determine whether permeability had influenced results. Both tubes were ultrasonically examined before they were pulled for further investigation. The subject tubes were pulled and forwarded to the W Steam Generator Technology and Engineering Center, for metallurgical and nondestructive examinations of the samples and the suspect indications. Preliminary reports disclosed the following:

° Burst Tests

Tube 3-92 The sample failed at 12,000 psi, at the location of a small gouge on the OD surface of the tube. The depth of the gouge was approximately 15% TW.

Tube 14-94 The sample failed at 12,300 psi, the point of failure was at the sample's midspan.

Results of a burst test performed on a, as manufactured tube section showed that it failed at 12,450 psi.

Post burst examination revealed both samples experienced uniform expansion prior to failure. The fracture surfaces and the OD surfaces, exhibited no evidence of corrosion. Multiple OD surface scratches were observed.

° Ultrasonic Examination (UT)

Both tube were UT examined by B&W, prior to pulling. Preliminary reports showed evidence of very shallow axial indications at different locations coincident with EC results.

° Radiography:

Tube 3-92 The radiographic film showed evidence of small indications approximately 0.1" long near the locations indicated by Eddy Current.

Tube 14-94 No evidence of indications, surface deposits observed on OD surface.

°Visual:

Tube 3-92 Small surface gauges observed near vicinity of X-Ray indications above. No evidence of cracking observed.

Tube 14-94 Evidence of surface deposits on OD, characterized as patches, were observed in the vicinity of X-Ray indications.

°Liquid Penetrant:

Results of this examination showed no evidence of cracking on either of the tube sections.

°Fractography:

Examination of the post burst fracture surfaces with scanning electron microscope (SEM) showed no evidence of stress corrosion cracking in either of the two tube sections.

In summary, preliminary results of examinations conducted on the subject tubes showed no evidence of significant indications i.e., stress corrosion assisted cracking on the sections of the subject tube samples submitted for investigation. W is continuing their investigation on these tubes and on the other four (4) tubes pulled for this purpose.

° Eddy Current Examination of S/G Tubes, Unit 2.

The scope of the examination in Unit 2 S/G(s), was essentially the same as in Unit 1, with the exception that hot leg tube examinations were not performed at this time. Procedures, Analysis Guidelines, technical expert evaluations, used in Unit 1 were also used in Unit 2 without exceptions.

Tubes examined with MRPC coil due to indications called by bobbin coil analysis were as follows:

S/G"A"	S/G"B"	S/G"C"	S/G"D"
463	446	427	516

Results from these examinations and evaluations by technical experts caused 12 tubes from each of the four steam generators to be plugged. By telephone, the inspector ascertained that the majority of these tubes were plugged because of dents and >40 TW material/volumetric type indications. There were approximately five (5) tubes identified as having crack like indications and the licensee was conducting a check of previous data for evidence relative to this condition.

Within the areas inspected violations or deviations were not identified.

3. Action on Previous Inspection Findings.

(Closed) Violation 50-369/92-05-01

This violation involved a failure to remove from service a S/G tube with an indication having through wall depth in excess of Technical Specifications allowable limits.

The licensee's response dated June 1, 1992 was reviewed and determined to be acceptable by RII staff. A summary of some significant corrective actions taken are as follows:

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

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

- a. Emphasis on the detection of freespan indications
- b. No minimum voltage threshold
- c. Report any and all indications of degradation regardless of depth
- d. Emphasis on scrolling the primary differential channel
- e. Investigation of positive responses on the 100 kHz absolute vertical strip chart
- f. Differential responses within specified defect plane
- g. Absolute responses within specified defect plane.

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

The eddy current analysis guidelines were revised to delete the "S/N" ratio limits of 5 to 1 that may have lead to a lack of conservatism in the eddy current results. This required that a signal influenced by noise would receive further evaluation or tests.

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

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

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

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 EC analysts to ensure a timely and accurate transfer of information concerning EC inspection need, progress of inspection and scheduling concerns.

The work schedule of the EC analysts and team members was reduced from six 12 hour days to six 10 hour days.

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

On the basis of these actions the inspector concluded that the licensee had determined the full extent of the subject noncompliance, performed the necessary follow-up actions to correct the present conditions and developed the necessary corrective actions to preclude recurrence of this problem. The corrective actions identified in the letter of response have been implemented.

#### 4. Exit Interview

The inspection scope and results were summarized on June 12, 1992, with those persons indicated in paragraph 1. The inspector described the areas inspected and discussed in detail the inspection results. No proprietary information is contained in this report. Dissenting comments were not received from the licensee.