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U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit No. 1; Docket No. 50-317
Steam Generator Tube Inspection Results

In the spring of 1996, Baltimore Gas and Electric Company conducted a scheduled refueling outage at Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 1. An inspection of the Unit 1 steam generator tubes was performed during the outage. The results of the Steam Generator Tube Inspection fell into the C-3 category, as described in CCNPP Technical Specification 4.4.5.2. A presentation was made to the Nuclear Regulatory Commission staff in Rockville, Maryland on June 13, 1996, in which the results of the inspection were provided. In accordance with Technical Specification 4.4.5.5.c, a written follow-up of this report, providing a description of the investigations conducted to determine the cause of the tube degradation and corrective measures taken to prevent recurrence is provided below.

INSPECTION SCOPE

The examination of Calvert Cliffs Unit 1 Steam Generators (Nos. 11 and 12) consisted of bobbin coil and motorized rotating plus point (MRPP) inspection technologies.

A. Bobbin Coil Inspections

The bobbin coil examinations for Steam Generator Nos. 11 and 12 included 100 percent bobbin coil full length examination of all inservice tubes.

B. Motorized Rotating Plus Point Inspections

The MRPP examinations for Steam Generator Nos. 11 and 12 included:

1. One hundred percent of the hot leg inservice tubes at the top of the tube sheet (TTS), (TTS+5" above to TTS-1" below).
2. Twenty percent of rows 1 and 2 (U-Bend Region). The vertical extent of the exam was from tube support 06H to tube support 06C.

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3. Twenty percent random sample of all the dented intersections ≥ 5 volts. Axial and circumferential indications were identified at the 9th tube support plate (TSP), the lowest solid TSP. Subsequently, 100 percent of the 9th TSP intersections were inspected. No degradation was identified at the other dented intersections.

4. One hundred percent of rows 6 through 12 in the Steam Blanket Region.

5. All unexpanded tubes, the full length of the tube sheet.

6. Rows 35 to 140 (Stay Dome/Arc Region). These upper bundle freespan inspections were conducted from the 4th TSP to vertical middle support in the areas identified by the Athos model, to be susceptible to dryout.

C. Special Motorized Rotating Plus Point Inspections

All MRPP inspections were performed using the "Plus Point" probe technology. All distorted bobbin coil indications and all percent through-wall indications identified by bobbin were dispositioned with the plus point probe.

EDDY CURRENT INSPECTION RESULTS

Attachment (1) contains the results of the MRPP and bobbin for Steam Generator Nos. 11 and 12. All steam generator tubes with crack-like indications, both circumferential and axial, all the anomalous indications (Volumetric and Plus Point Indication), and all indications greater than 40 percent through-wall were removed from service.

IN-SITU PRESSURE TEST RESULTS

Attachment (2) contains the scope and criteria for the in-situ pressure testing. In-situ pressure tests were conducted on two tubes in Steam Generator No. 11 and seven tubes in Steam Generator No. 12. The tubes selected for in-situ pressure testing contained the largest axial voltage, the largest axial length, the largest circumferential voltage, and the largest circumferential length indications at TTS. These indications also contained the deepest estimated percent through-wall. The test methods used included both localized and full tube length.

The most limiting case for CCNPP is pressurization without burst to three times normal differential operation pressure (3 x 1400 psi = 4200 psi). The minimum test pressure for tubes with axial indications was set at 4750 psig to account for temperature correction. The minimum test pressure for tubes with circumferential indications was set at 5300 psig to account for temperature correction and possible axial loading due to tube lock effects. Three of the tubes exhibited leakage. All tubes were pressurized greater than 4750 psig, no tubes burst.

Six of the nine tubes were tested to pressures in excess of the above values to further verify the substantial remaining structural integrity of the defective tubes. The test pressure achieved was limited by the test device. The test pressures reached a maximum pressure of 5750 psig.

The test results of the in-situ pressure test are summarized in Attachment (3).

All steam generator tubes in-situ pressure tested were found to have exceeded the Regulatory Guide 1.121 requirements for structural integrity.

TUBE PULL TEST RESULTS

Three tubes were removed from Steam Generator No. 12 for laboratory analysis. The tubes pulled included two with multiple defects in the upper bundle Freespan Region (R46L76, R111L67) and one with a combined axial/circumferential defect at the TTS (R67L71) as identified by field eddy current testing. Laboratory testing performed has included visual, eddy current, and ultrasonic examinations, burst testing, metallurgical analysis, scanning electron microscope examinations, and chemical analysis of tubes and tube deposit samples. A chemical cleaning test has been performed on a tube section with heavy deposits.

Major results of the exam are:

- Burst tests of eight tube sections with freespan defects have yielded burst pressures in excess of 10,000 psi. No tube section leaked prior to bursting, indicating none of them had inservice leaks. These burst pressures are essentially equivalent to burst pressures of tubes with no defects. The burst tests prove the tubes retained ample structural integrity to withstand any postulated accident as well as normal operating conditions.

- In tubes R111L67 and R46L76, a total of 66 individual eddy current indications were identified by re-analysis of the field eddy current data. These defects are all in the Upper Bundle Region between the 5th and 9th support, a region where indications have not been previously observed in Calvert Cliffs' steam generators. An attempt is being made to locate and determine the size of each of these defects through the destructive exam. A small number of additional defects have been located by the destructive examination which were not identified by the field eddy current testing. The data will be used to generate a probability of detection curve for these type of defects.

- The tubes had heavy deposits in the region between the 5th and 9th support. Chemical analysis of these deposits indicate they are mostly iron oxide in the form of magnetite (Fe_3O_4). The deposits also include a larger amount of silica than is typically seen in steam generator tube deposits, and isolated copper deposits.

- All defects are intergranular stress corrosion cracking (IGSCC). The destructive exam confirmed the defects are all axially oriented in tubes R111L67 and R46L76. The defect at the TTS in tube R67L71 was found to consist of axial cracks only.

CAUSE OF TUBE DEGRADATION AND CORRECTIVE MEASURES

Three tubes were pulled from Steam Generator No. 12 for laboratory analysis, to fully assess the cause of the tube degradation and to develop effective corrective measures to mitigate further degradation. All defects are IGSCC. The IGSCC was all outside diameter initiated. This type of tube degradation is due to material stresses, environment, and age. The size distribution of the indications is very small and are normal age related type indications. A correlation between steam generator upper bundle freespan tube cracking and the steam generator dryout region was established. The ATHOS model developed for the CCNPP Unit 1 steam generators predicted the dryout areas which supported the indications detected in

the upper bundle region of the steam generators. All steam generator tubes with crack-like indications, both circumferential and axial, all the anomalous indications (Volumetric and Plus Point Indication), and all indications greater than 40 percent through-wall were removed from service. We plan to re-inspect the appropriate steam generator tubes during the next scheduled Unit 1 refueling outage (spring 1998).

Should you have questions regarding this matter, we will be pleased to discuss them with you.

Very truly yours,

John T. Camell

for
P. E. Katz
Plant General Manager

PEK/RCG/bjd

Attachments: As stated

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ATTACHMENT (1)

RESULTS OF THE MOTORIZED ROTATING PLUS POINT AND BOBBIN FOR STEAM GENERATOR NOS. 11 AND 12

The following outline summarizes the final results of this examination.

INDICATIONS	STEAM GENERATOR NO. 11	STEAM GENERATOR NO. 12
SAI, MAI @ TTS	116	166
SCI, MCI @ TTS	56	33
VOL @ TTS	0	1
SVI @ TTS	7	7
SAI, MAI @ 09H	15	5
SCI, MCI @ 09H	2	5
SAI, MAI, MSI - FREESPAN	164	391
PPI - FREESPAN	55	73
VOL	3	4
0-19%	129	150
20-39%	54	90
40-100%	8	18
TUBES REPAIRED	340	500

NOTE: Numbers denote indications. Some tubes contain multiple indications.

LEGEND:

MAI	Multiple Axial Indication
MCI	Multiple Circumferential Indication
MSI	Multiple Single Indication
PPI	Plus Point Indication
SAI	Single Axial Indication
SCI	Single Circumferential Indication
SVI	Volumetric Pit Indication
TTS	Top of the Tube Sheet
VOL	Volumetric Indication

ATTACHMENT (2)

SCOPE AND CRITERIA FOR THE IN-SITU PRESSURE TESTING

These tubes were selected for testing:

STEAM GENERATOR NO. 11

Row, Line	Flaw Type	Flaw Location	Flaw Length	Flaw Voltage	Region
100,88	PPI	09H + 11.55	4.5 inches	1.57	Freespan
95,129	PPI	DH + 4.00	2.5 inches	1.49	Freespan

STEAM GENERATOR NO. 12

Row, Line	Flaw Type	Flaw Location	Flaw Length	Flaw Voltage	Region
9,129	SAI	VM	1.0 inches	3.70	Steam Blanket
9,137	SAI	VM	1.0 inches	3.78	Steam Blanket
90,84*	MCI	TSH + 0.10	0.9 inches	3.10	TTS
50,80	MCI	TSH + 0.15	2.3 inches	0.85	TTS
74,100	SCI	TSH + 0.01	2.0 inches	6.51	TTS
76,78	SAI	TSH + 1.35	1.6 inches	3.50	TTS
82,90	MAI	TSH +0.61	1.1 inches	38.11	TTS
72,98	SAI	TSH + 0.32	0.6 inches	21.39	TTS

* This tube was not tested due to the test fixture not being capable of entering the tube due to a physical obstruction.

There were no Freespan Region axial indications in-situ pressure tested due to the pulled tube laboratory burst test demonstrating the worst case characteristics for all freespan axial indications recorded this outage

The tubes selected exhibited the worst case characteristics for the listed indication types in their particular region of the steam generators. For example:

⇒ There are no TTS axial indications in either Steam Generator Nos. 11 or 12 with a higher voltage than tubes 82,90 and 72,98 in Steam Generator No. 12.

⇒ There are no TTS axial indications in either Steam Generator Nos. 11 or 12 with greater lengths than 76,78 and 82,90 in Steam Generator No. 12.

⇒ There are no TTS circumferential indications in either Steam Generator Nos. 11 or 12 with a higher voltage than tube 74,100 in Steam Generator No. 12.

⇒ There are no TTS circumferential indications in either Steam Generator No. 11 or 12 with greater lengths than 50,80 and 74,100 in Steam Generator No. 12.

⇒ There are no Steam Blanket Region axial indications in either Steam Generator Nos. 11 or 12 with greater lengths or voltages than 9,129 and 9,137 in Steam Generator No. I2.

⇒ There are no Freespan PPIs in either Steam Generator Nos. 11 or 12 with greater lengths or voltages than 100,88 and 95,129 in Steam Generator No. 11.

LEGEND:

DH	Diagonal Support Hot Leg
MAI	Multiple Axial Indication
MCI	Multiple Circumferential Indication
PPI	Plus Point Indication
SAI	Single Axial Indication
SCI	Single Circumferential Indication
TSH	Tube Sheet Hot Leg
TTS	Top of the Tube Sheet
VM	Vertical Middle Tube Support

ATTACHMENT (3)

SUMMARY OF THE IN-SITU PRESSURE TEST RESULTS

STEAM GENERATOR NO. 11

Row, Line	Flaw Type	Flaw Location	Flaw Length	Flaw Voltage	Test Pressure	Tube Leakage?
100,88	PPI	O9H + 11.55	4.5 inches	1.57	5,750 psig	None
95,129	PPI	DH + 4.00	2.5 inches	1.49	5,750 psig	None

STEAM GENERATOR NO. 12

Row, Line	Flaw Type	Flaw Location	Flaw Length	Flaw Voltage	Test Pressure	Tube Leakage?
9,129	SAI	VM	1.0 inch	3.70	5,750 psig	None
9,137	SAI	VM	1.0 inch	3.78	5,750 psig	None
50,80	MCI	TSH + 0.15	2.13 inches	0.85	5,750 psig	None
74,100	SCI	TSH + 0.01	2.0 inches	6.51	5,300 psig	Yes
76,78	SAI	TSH + 1.35	1.6 inches	3.50	5,300 psig	Yes
82,90	MAI	TSH + 0.61	1.1 inches	38.11	5,750 psig	None
72,98	SAI	TSH + 0.32	0.6 inches	21.39	4,750 psig	Yes

LEAK RATE DATA

Row, Line	Initial Leak Pressure	Initial Leak Rate	Leak Pressure	Leak Rate	Leak Pressure	Leak Rate	Leak Pressure	Leak Rate
76,78	4,750 psig	Not Measured	5,300 psig	81.2 gpd	NA	NA	NA	NA
74,100	4,200 psig	41.9 gpd	5,300 psig	87.5 gpd	NA	NA	NA	NA
72,98	2,800 psig	Not Measured	3,000 psig	17.8 gpd	4,200 psig	87.5 gpd	4,750 psig	111.6 gpd

All tubes were reinspected with plus point upon completion of testing.

ATTACHMENT (3)

SUMMARY OF THE IN-SITU PRESSURE TEST RESULTS

LEGEND:

DH	Diagonal Support Hot Leg
MAI	Multiple Axial Indication
MCI	Multiple Circumferential Indication
PPI	Plus Point Indication
SAI	Single Axial Indication
SCI	Single Circumferential Indication
TSH	Tube Sheet Hot Leg
VM	Vertical Middle Tube Support