Consumers Power

POWERING MICHIGAN'S PROGRESS

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January 22, 1988

Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

DOCKET 50-255 - LICENSE DPR-20 - PALISADES PLANT -
DESCRIPTION OF DECEMBER, 1987 STEAM GENERATOR TUBE LEAK AND STEAM GENERATOR EDDY CURRENT EXAMINATION

Following an increase in condenser off-gas radiation on December 3, 1987, subsequent sampling indicated a primary to secondary leak in the Palisades "B" steam generator. The leak rate was determined to be approximately 0.072 gallons per minute which remained under the Plant Administrative limit of 0.1 gpm and the Technical Specifications limit of 0.3 gpm. A controlled plant shutdown was accomplished on December 4, 1987. Inspection of the "B" steam generator visually identifed the leaking tube and by a helium test confirmed the location of the leaking tube. In addition, the Eddy Current Examinations properly detected a throughwall condition. The leaking tube is identified as Item 8 in Table 3.1 that is attached.

Because of the forced outage and inspection to find the source of primary to secondary leakage in the steam generators, the decision was made to complete the steam generator inservice inspection program which had been scheduled for April, 1988. Through the inspection program, we kept the NRC staff informed of developments as they arose.

We have agreed with the NRC Palisades Project Manager to provide the attached description of the tube leak and a summary of the eddy current examination results for the steam generator tubes that were plugged during this outage. A 30-day Steam Generator Inservice Inspection Report will also be submitted in accordance with the Palisades Technical Specifications by February 10, 1988. That report will provide, in greater detail, the complete results of the eddy current testing program.

Eighteen steam generator tubes, described in Table 3.1, were plugged during this outage; four in the "A" steam generator and fourteen in the "B" steam generator. Misplugging, in 1985, of two other tubes in the "B" steam generator resulted in the opposite ends of both these tubes being plugged also.

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The attachment also contains a summary comparison of the July 15, 1987, North Anna tube rupture to the tube leak event at Palisades.

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Administrator, Nuclear Licensing

CC Administrator, Region III, NRC
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Attachment

ATTACHMENT

Consumers Power Company
Palisades Plant
Docket 50-255

"B" STEAM GENERATOR TUBE LEAK AND EDDY CURRENT EXAMINATION SUMMARY

January 22, 1988

Pages 14

OC0188-0017-NL02

"B" Steam Generator Tube Leak and

Eddy Current Examination Summary

January 22, 1988

Contents

1. A description of the tube leak event
2. The size and nature of the applied eddy current (ECT) inspection
3. The observed degradation in the context of previous Palisades experience
4. The relationship between this Palisades experience and the July 15, 1987 North Anna Unit 1 tube rupture event

1. Description of Event

At approximately 1920 on December 3, 1987, the condenser off-gas radiation monitor began to alarm in the control room. Sampling and analysis of the condenser off-gas flow confirmed that the indicated increase was actual. A calculation of the leak rate based upon the observed off-gas contamination produced a value of 0.023 gallons per minute. At 2330, a three hour PCS leak rate produced the value of 0.192 gallons per minute unidentified. The unidentified PCS leak rates for December 1, 2, and 3 were reported as 0.082, 0.022, and 0.01 gallons per minute respectively.

Subsequent to several conversations between onsite shift management and offsite plant management, the plant Operations Superintendent arrived on site at 2330, and managed the decisions regarding shutdown. The decision to shut down at a controlled rate of about 12% per hour was implemented at 0040 on December 4, 1987.

Plant shutdown was routine, except for the isolation of the "B" steam generator blowdown. The reactor was tripped at 1358 on December 4, 1987. Cold shutdown boron concentration was reached at 1413. Cold shutdown temperature was reached on December 6, 1987 at 0906.

Prior to the event, the plant had been operating at essentially full load since the November 13, 1987 start-up from the scheduled maintenance outage.

At no time did the steam generator tube leakage appear to approach the Technical Specification 3.1.5 limit of 0.3 gallons per minute (steady state, or 0.6 gallons per minute transient).

In recent history, Palisades has experienced tube leakage of a magnitude requiring plant shutdown only twice; in 1982, and now in December 1987. In neither case was the leak rate more than one gallon per minute. The events described above are listed below in Table 1.1. Table 1.2 lists the chemistry sampling associated with the tube leak.

TABLE 1.1

Steam Generator Tube Leak - Operational Sequence

12/3/87

* 1920 - Condenser off-gas monitor alarming - chemistry sampling requested.
* 2020 - Off-gas analysis confirms the increase of fission products in the secondary system.
* 2130 - Duty and Call Superintendent informed of plant status.
* 2324 - A three hour PCS leak rate indicates the "unidentified" leakage to be about 0.192 gallons per minute at steady full power.
* 2325 - Primary to secondary leakage calculated to be about 0.023 gallons per minute. Informed the Duty and Call Superintendent.

12/4/87

* 0040 - Shutting down @ 12% per hour due to continuously increasing off gas monitor readings.
* 0110 - Informed Duty and Call Superintendent of plant status.
* 0130 - Informed the NRC resident of the plant shutdown.
* 0230 - Chemistry sample indicates primary to secondary leakage is approximately 0.072 gallons per minute.
* 0507 - Stopped power decrease to perform heat balance and perform steam generator sampling to confirm which one is leaking.
* 0515 - Resumed power decrease at 12% per hour. "B" steam generator blowdown isolated.
* 0658 - Stopped power decrease for shift turnover and heat balance.
* 0811 - Resumed power decrease at 6% per hour.
* 1152 - Turbine off line.
* 1358 - Reactor tripped.
* 1413 - PCS boron at 1111 PPM (cold shutdown concentration).

12/6/87

* 0906 - Reached cold shutdown temperature on the PCS.

TABLE 1.2

Chemistry Sampling Associated With the Tube Leak

12/3/87

* 1920 - Condenser off-gas (high alarm)
  Xenon-133 = 1.74E-04 microcuries/cc

* 2020 - "A" Steam Generator
  Gross gamma < 6.4E-06 microcuries/ml
  - "B" Steam Generator
  Gross gamma < 6.4E-06 microcuries/ml
  - Condenser off-gas
  Xenon-133 = 1.8E-04 microcuries/ml

* 2330 - Condenser off-gas
  Xenon-133 = 3.9E-04 microcuries/ml

12/4/87

* 0030 -

	"A" Steam Generator (Gamma Spec)#	"B" Steam Generator (Gamma Spec)#
I-131	< detectable	1.8E-07
I-132	< detectable	3.7E-07
I-133	< detectable	2.9E-07

* 0220 - Condenser off-gas
  Xenon-133 = 1.2E-03 microcuries/ml

* 0300 -

	"B" Steam Generator (Gamma Spec)#
I-131	2.0E-06
I-132	2.3E-06
I-133	3.5E-06

* 0400 -

	"A" Steam Generator (Gamma Spec)#	"B" Steam Generator (Gamma Spec)#
I-131	< detectable	3.4E-06
I-132	< detectable	3.3E-06
I-133	< detectable	6.1E-06

* 0500 - Condenser off-gas
  Xenon-133 = 7.6E-06 microcuries/ml

* 0615 - Condenser off-gas
  Xenon-133 = 9.7E-05 microcuries/ml

- other isotope results not printed here

2. Size and Nature of the Eddy Current Examination

The eddy current (ECT) examination of the steam generators was comprised of two parts; the Technical Specification required portion and supplementary portions due to observed tube damage. Table 2.1 provides the details of the examination performed. This examination was performed to bound the observed damage, and to comply with regulatory requirements for the planned spring 1988 maintenance outage.

Consistent with the example provided in Reg Guide 1.83, the inspection provides considerable confidence that tube damage of the nature that caused the leak event is not a pervasive problem in either steam generator.

As shown on Table 2.1, a supplementary sample required by regulation, was initiated upon the detection of a crack-like indication in the "B" cold leg random sample.

In order to bound the probable area associated with the cold leg cracking indications, an examination of the location of past such indications (1983 and 1987) was performed. One third of the remaining tubes in this area ("B" S/G cold leg) were examined. Three additional crack-like indications were detected within this area and plugged. As a further conservative measure, the most recent 1983 or 1985 historical signal data for each of the tubes within the bounded area which had not been tested in 1987 (956 tubes) was reviewed. Only one additional crack-like indication was detected.

It should be noted that there is no such "area" associated with cold leg bend cracking in the "A" steam generator. In 1983, only four such (cold leg bend crack-like) defects were noted in performing the "A" steam generator 100% inspection (six such defects were plugged in the hot leg bend). The 1987 inspection has revealed no such "A" steam generator bend defects.

The motorized rotating pancake coil (MRPC) was used to examine locations where 4C4F signals were indeterminate as to flaw condition. By using this technique, five tubes potentially requiring plugging due to conservative interpretation were shown to be acceptable. Another use of the MRPC was to provide additional sizing information for selected defects. The result of these examinations confirms that the defects detected in 1987 are of the same size or smaller than those observed in 1983. The MRPC is not considered a "pull-through" technique, but rather a special tool to examine select areas of special interest.

The equipment used during this inspection is identical to that used during the 1985 inspection, except for the MRPC probe and its signal analysis by a Zetec MIZ-18 analyzer. As in the previous two inspections, the 540 SFW probe was employed to detect and size "wastage" type defects. The 4C4F probe was used to detect and size circumferentially oriented defects, including volumetric IGC and cracking. The Zetec MIZ-12 signal analyzer was used with both of these probes.

TABLE 2.1

Steam Generator Eddy Current Examination Summary (1987)

Eddy Current Examination	Test Type	Purpose	Primary Information	Approximate Number of Tubes Examined: Generator "A" Hot	Generator "A" Cold	Generator "B" Hot	Generator "B" Cold
540 SFW	Differential Coil Multifrequency Multiparameter	Flaw ≥ 30% in either of past two inspections (Random sample - 2% HL, 1% CL) - TS 4.14.2	Wastage Pitting	677 (10.4%)	70 (1.1%)	550 (8.5%)	68 (1.0%)
4C4F	Differential Multicoil Multifrequency Multiparameter	Tube exams for 30-100% both with and without denting (Random sample - 2% HL, 1% CL) - TS 4.14.2	IGC Circ. Cracking	730 (11.2%)	189 (2.9%)	831 (12.8%)	133 (2.1%)
Tubes in Vicinity of Leaker	4C4F 540 SFW 540F	Inspection of tubes surrounding leaker - Management decision	Circ. Cracking IGC Wastage			40	
6% Supplementary Sample	4C4F	Locate additional flaws. Sample was triggered when one crack-like indication was found in the "B" cold leg random sample - TS 4.14.3	Circ. Cracking IGC				389 (6.0%)
6% Voluntary Area Sample	4C4F	Locate additional flaws in the area primarily associated with 1983 and 1987 crack-like indications - Management decision	Circ. Cracking IGC				398 (6.1%)
MRPC	Motorized Rotating Absolute Pancake Coil	In-depth Flaw Characterization - Management decision	Circ. Cracking IGC Wastage	1	1	3	11
540F	Differential Coil Pull-Thru	Sludge Depth Examination - Management decision	Sludge Depth	20		21	
Profilometry	Eddy Current Proximity Method	Examination of dent profiles - Management decision	Dent Profiles and Deformation	622 (9.5%)	329 (5.0%)	531 (8.2%)	336 (5.2%)

"A" S/G: 6,516 Unplugged Tubes, "B" S/G: 6,482 Unplugged Tubes (Reflects tube plugging as of the 1985 ECT inspection.)

3. Observed Degradation

The 1987 examination produced a list of 18 tubes that require plugging in accordance with our tube plugging criteria. Table 3.1 provides a listing of the available information associated with these tubes. Table 3.2 summarizes the data, and the concluding observations.

The eddy current probe used to collect the information upon which the observation is made is given in parentheses; for example (4C4F). The designation "XX" is used to represent crack-like defects.

TABLE 3.1

1987 Tube Plugging List Due To Damage[1]

	SG	QUAD	LINE	ROW	ELEVATION	DEFECT
1.	A	3	44	87	V2	XX

* Post inspection reanalysis of the defect indicated that there were actually two cracks detected with the 4C4F probe, one at V2 and one at V4. The MRPC data only saw one defect at V2.[2]
* Defect at V2 was present in 1985, and not considered to have changed.
* Defect at V2 is actually six different small unconnected areas distributed around 360 degrees of the tube (MRPC).
* MRPC data is indeterminate as to whether the defect at V2 is contained within the strap or not.

	SG	QUAD	LINE	ROW	ELEVATION	DEFECT
2.	A	4	49	80	3	67%

* 40% in 1983, 49% in 1985, and 67% in 1987 (4C4F). This defect clearly progressed with time.
* The 4C4F signal shows a similarity to a crack-like indication, but it has considerable axial involvement which is indicative of a volumetric type defect.
* MRPC sizing: 38 mils x 411 mils circumferentially orientated.
* The MRPC results on this defect closely resemble the MRPC results on the leaking defect.[2]
* The defect appears to be inside the lower edge of the tube support plate (TSP) (MRPC).
* There does not appear to be a dent present of any major magnitude (4C4F).

	SG	QUAD	LINE	ROW	ELEVATION	DEFECT
3.	A	3	6	139	12	BLOCKED

* The tube is blocked to a 540 SFW Probe at TSP #12.

	SG	QUAD	LINE	ROW	ELEVATION	DEFECT
4.	A	3	13	138	12	BLOCKED

* The tube is blocked to a 540 SFW Probe at TSP #12.

[1]The information provided in this table reflects ECT data interpreter commentary.
[2]At this time CPCo has only qualified the MRPC technique for the detection and sizing of wastage type indications and for the detection of circumferential cracking. The MRPC has not been qualified by CPCo to detect or size intergranular corrosion, nor has its flaw characterization ability (ie, determining flaw orientation and measuring flaw area) been fully qualified. Until such work is performed the MRPC results for these indications (Nos 1 and 2) are considered inconclusive by Consumers Power Company. The qualification work discussed here is scheduled to be performed prior to the next scheduled eddy current inspection.

5. B 1 9 64 CL BEND XX

* The defect has some axial and circumferential extent (MRPC).
* The defect is located inside (about 1.2") the lower portion of the diagonal strap (MRPC).
* The defect is close to the diagonal strap, but not in contact (MRPC).
* The defect is very small and was present in 1983. The defect is unchanged (4C4F).

6. B 1 25 34 CL BEND XX

* The defect was present in 1983, and is unchanged.
* The defect is right in the middle of the diagonal strap. The defect is very small - 4 x 111 mils (MRPC).

7. B 1 29 40 CL BEND XX

* The defect was present in 1983, and is probably unchanged.
* There are actually three axially spaced defects, located from the middle to the lower edge of the diagonal strap. The largest is approximately 0 x 61 mils (MRPC).

8. B 2 35 122 13 XX - LEAKER

* The defect is at the lower edge (both inside and outside) of the TSP. There is a small dent in the defect area that appears unchanged (4C4F) from 1983 (MRPC).
* The defect is approximately 8 mils axial and 500 mils circumferential.
* The defect clearly changed from 1983.

9. B 2 37 96 12 69%

* The defect appears axially orientated (MRPC).
* The defect is both inside and outside of the TSP on the bottom of the TSP (MRPC).
* The defect is about 15 degrees on the circumference, and 306 mils axial in size (MRPC).
* The defect appears to have changed substantially from 1985.

10. B 2 42 95 12 73%

* The defect appears axially orientated (MRPC).
* The defect is both inside and outside of the TSP on the bottom of the TSP (MRPC).
* The defect is about 75 degrees on the circumference, and about one inch axial in size (MRPC).
* The defect appears to have changed significantly from 1985.

11. B 3 26 27 V3 XX

* The defect definitely increased from 1983 to 1987.
* The position of the defect relative to the V3 (no scallop bar region) is uncertain (4C4F).
* The defect was not rotated with the MRPC.

12. B 4 10 77 CL BEND XX

* The 1983 data was saturated, due probably to bending ovalness (4C4F). The 1987 signal is good.
* The defect is located roughly in the center of the diagonal strap (MRPC).
* There are actually two separate, joined defects comprising the flaw (MRPC).
* The flaw is close to contacting the diagonal strap (MRPC).
* The defect is approximately 0 x 20 mils in size, circumferentially orientated (MRPC).

13. B 4 20 55 CL BEND XX

* The defect is actually three separate areas in the lower edge of the diagonal strap (MRPC).
* The defect was present in 1983, but not observed in 1985 (probably due to probe orientation relative to the flaw).
* The defect is small and about 45 degrees from the strap contact point (MRPC).

14. B 4 20 57 CL BEND XX

* The defect is unchanged from 1983 to 1987.
* The defect is inside the diagonal strap area near the bottom edge. The approximate size is 0 x 56 mils circumferentially orientated. The defect is nearly in contact with the strap (MRPC).

15. B 4 20 85 CL BEND XX

* The 1983 signal is confusing - not interpreted.
* There was no defect present in 1985.
* In 1987 the 4C4F signal is in saturation because of the bending ovalness.
* The signal is in an area outside of the diagonal strap.
* The signal is probably not representing a flaw, however, the tube is being plugged due to uncertainty about what is present.

16. B 2 8 121 HL BEND BLOCKED

* The tube is blocked to a 540 SFW probe at the hot leg bend.

17. B 1 12 33 CL BEND XX

* This tube was not inspected in 1987. It is being plugged based upon a review of 1983 cold leg bend data in the area most affected by XX signals in 1983. The more conservative 1987 interpretation of the 1983 data resulted in the designation of the defect as "XX".

18. B 2 14 85 3 51%

* This tube was examined in 1985, and a comparison of the 1985 and 1987 4C4F signals indicates that there is essentially no change. The defect signal was called 45% in 1985.

TABLE 3.2

Summary of Results and Observations

1. A grouping of defect types produces the following list:

Number	Type	Steam Generator
11	XX	(10 - "B", 1 - "A")
4	Degradation	(3 - "B", 1 - "A")
3	Blocked	(1 - "B", 2 - "A")

2. Of the 208 "differences" (ECT data indicating ≥ 10% change from previous inspections) resulting from the 1987 inspection, only one was actually due to increased degradation of the tube (Tube A-Q2-L25-R86, Level 4 went from "OK" to 22%). Of the 11 crack-like indications plugged, 7 were clearly present in the 1983/1985 data. This previous "non-reporting" of defects can be attributed to the following factors:

   * Extremely small amplitude signal response (< 1/4 volt)
   * Insufficient interpreter indoctrination to the technique in 1983
   * Poor signal to noise ratio that is inherent with the 4C4F technique

3. Considering only 4C4F examinations, the number of tubes with known, substantial (10% or greater), further degradation is small in relation to the sample size. Of the 18 tubes being plugged due to ECT signals, only 5 have clearly increased in magnitude or penetration. The rest of the indications are unchanged (or uncertain), and are being plugged based upon "improved" interpretation, or tube blockage (denting).

   Number of (half) tubes inspected - 2,710 (about 10.3%)
   Number with significantly increased degradation - 5 (0.18% of sample)

   * B-Q2-L35-R122
   * A-Q4-L49-R80
   * B-Q2-L37-R96
   * B-Q3-L26-R27
   * B-Q2-L42-R95

   This data does not suggest a pervasive, progressive problem.

4. The location of the tubes with increased degradation does not appear to show an obvious area pattern. The blocked tubes are periphery tubes near TSP lugs. Most of the "B" cold leg bend crack-like defects observed in 1987 are within the area prescribed by the 1983 results (the basis for the additional 6% voluntary sample).

5. The MRPC data for the leaking tube (B-Q2-L35-R122) indicates the defect is extremely narrow (2 - 8 mils axial). Since the MRPC has not been qualified on volumetric IGC, it is not possible at this time to relate this data to the defects observed in tubing removed in 1983.[1]

6. All of the defects observed in 1987 were similar in 4C4F signal presentation to those observed in 1983. The MRPC data indicates that none of the defects, including the leaking defect were larger than those analyzed in the 1983 tube plugging criteria analysis.[1] There is not any data to suggest that there is a new damage phenomena present.

7. The secondary side inspection visual examination of the upper portion of the steam generator tube bundle does not show significant structural damage has occurred. Some flow hole ligament cracking is observed. No closing of the TSP - wrapper annulus has yet occurred (visually). It appears that denting stresses are accumulating on the periphery, but that serious TSP damage has as yet not occurred.

[1]See Footnote 2 on Page 8.

4. North Anna Unit 1 Tube Rupture Event - 7/15/87

As described in the above section, the probable mechanism for the observed tube damage is that of IGC. Because of the seriousness of the North Anna event, a discussion is provided to demonstrate that the recent Palisades damage evidence is not similar to that observed at North Anna Unit 1.

The North Anna event has been analyzed to have been caused by fatigue according to publicly available literature. A metallurgical examination found no evidence of corrosion. The failure appeared to be OD initiated. It occurred approximately one-half inch above the top (drilled) support plate roughly in the middle of the cold leg (Row 9, Column 51). A detailed understanding of the mechanism is not publicly available, however the following understanding is provided (via communication with Virginia Power personnel):

A. Energy from the crossflow of secondary coolant in the bend region resulted in vibration of the tube piece above TSP #7. This vibration was limited to this portion of tubing due to the denting at TSP #7.

B. Westinghouse stress calculations indicate that the OD stress profile changes from a compressive value inside the dented TSP to a maximum tensile hoop stress about 0.2 - 0.3 inches above the top of the TSP. These calculations seem to indicate that the failure occurred where it might be predicted from an axial OD stress profile.

C. The Westinghouse Model 51 design provides for antivibration bar (AVB) support down to Row 9. North Anna eddy current testing indicated that in Rows 9, 10, and 11, some tubes were not adequately supported. The tube span in Rows 2 to 8 were considered to be too short to support the destructive vibration. Row 1 is plugged. Following the event, some tubes in Rows 9, 10, and 11 were plugged due to a lack of AVB support. All six North Anna steam generators were treated this way. The ruptured tube did not have adequate AVB support.

D. Metallography indicated the failure had occurred very rapidly (less than a day from initiation to rupture).

E. No ECT "precursors" were observed. Tubes were plugged preventively based not upon observed tube condition, but upon AVB support condition.

A discussion of the relevant Palisades tube damage information provides reasonable assurance that the likelihood of a North Anna type rupture occurring at Palisades is not increased by the implications of the recent Palisades tube leak. Specifically:

1. All Palisades tubes are supported in their bend region by diagonal "batwing" straps. This effectively reduces the influence of secondary coolant crossflow on the bend region.

2. The bend defects (XX) are contained within the diagonal straps. A phone conversation with a CE structural analysis source indicates that vibratory stresses affecting the bend areas should be greater just outside the strap than inside the strap. The crack-like defects in the bends may more likely be attributed to shallow IGC in the strap crevice areas, augmented by residual stresses from tube bending. Because of their location in the tube bundle, no samples are considered available for removal and metallographic examination.

3. The bend defects appear to have been present for a long time based upon a historical review of ECT signals. No signal interpreted as a crack-like defect in the bend area has been shown to be "new" based upon such reviews of past signals. The fact that such defects are being "observed" now is due entirely to more conservative interpretation, or better coil position relative to the extremely small defect during this examination.

4. None of the bend defects have ever gone through-wall. This is a significant fact relative to the bend area defects.

5. Observed XX or "deep" IGC in the Palisades steam generators has occurred predominantly at "upper" support plates either within or just below the TSP. This statement is founded upon the removed 1983 samples and the 1987 leaking tube.

The current sampling program requirements for monitoring steam generator tube leakage are contained in Chemistry Procedure COP 11 and Technical Specification Surveillance Test Procedure DWC-4. The gross gamma counts are monitored daily on the steam generators. Once per week, a gamma spectral analysis is performed on steam generators, and "dose equivalent iodine" values are calculated. These activities are routine.

The primary on-line monitor for primary to secondary system leakage is the condenser off-gas monitor. When this monitor is out of service, twice daily sampling of that fluid is required. A brief review of these requirements and the sampling indicates that immediate backup analysis was performed to confirm the off-gas monitor alarm. Such sampling continued until the turbine was removed from service.