UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

OPERATING CYCLE EVALUATION

VIRGINIA ELECTRIC AND POWER COMPANY

NORTH ANNA UNIT 1

DOCKET NO. 50-338

1.0 INTRODUCTION

North Anna Unit 1 shut down on December 23, 1991 for a mid-cycle steam generator (SG) tube inspection outage. During this outage an inservice inspection of the SG tubes was performed in accordance with Technical Specification 4.4.5. The results of the SG tube inspection were found to be in Category C-3 (as defined in Technical Specification 4.4.5.2) for each of the three steam generators. Prompt notifications of these Category C-3 findings were provided to the NRC staff on January 10, 1992 for SG C, on January 20, 1992 for SG A and on January 24, 1992 for SG B pursuant to Technical Specification 4.4.5.5.c and 10 CFR 50.73.

By letter dated March 2, 1992, the licensee requested NRC approval to return to power operation following this mid-cycle SG tube inspection outage. NRC approval is required pursuant to Technical Specification Table 4.4-2 whenever the inspection results for at least two of the three SGs are Category C-3. To support this request, the licensee met with the staff on March 2, 1992 to discuss the inspection results and the licensee's evaluation of these results. By letter dated March 23, 1992, the staff subsequently gave approval for plant restart and operation through January 1993. In the March 23, 1992 letter, the licensee was requested to submit an analysis confirming that the maximum end-of-cycle (EOC) crack sizes at the tube support plates (TSPs) will be within the Regulatory Guide 1.121 criteria. The licensee has since submitted, by letter dated May 1, 1992 (Serial No. 92-141A), a formal report (Westinghouse WCAP-13326) containing both the information requested and the information presented during the March 2, 1992 meeting.

2.0 DISCUSSION

The mid-cycle SG tube inspection program was extremely comprehensive, consisting of the following elements:

- A 100% full length inspection was performed with a bobbin coil probe for all available tubes in all three SGs except for Row 2 U-bends.

- A 100% inspection of the tube-to-tube support plate intersections was performed with an 8x1 probe on the hot leg side up to the 7th tube support plate. A comparison test of the 8x1 arrayed pancake probe and rotating pancake coil (RPC) probe on indications at the TSPs was performed. The comparison test showed that it was necessary to make conservative and probably false 8x1 calls to achieve more than 90% detection of the signals identified by RPC testing. Therefore, the use of the 8x1 probe data with a high overcall rate and RPC verification was judged to be less efficient than RPC testing alone.

- A 100% inspection of hot leg TSP locations was performed with an RPC probe.

- A 100% inspection of WEXTEX expansion-transition locations (at the top of tubesheet) was performed with an RPC probe on the hot leg side of each of the three SGs. These inspections were intended to provide sensitivity to circumferential cracks at this location.

- An RPC probe inspection of all row 2 U-bends was performed to ensure optimal sensitivity to stress corrosion cracking (SCC) at these locations.

- RPC probe inspections were performed for all tubes at locations exhibiting bobbin indications to more fully characterize these indications. RPC probe inspection of special interest tubes identified in the December 1991 reanalysis of the eddy current data from the previous outage was performed.

- All eddy current data was analyzed independently by two analysts. Resolutions of conflicts arising between these two analysts were performed by Westinghouse lead analysts and overseen independently by Virginia Power Quality Assurance.

The number and attribution of pluggable indications found during the course of the mid-cycle inspection were as follows:

Attribution	No. of Tubes with Pluggable Indications
Cracks at WEXTEX transition axial or circumferential	36
Free span	3
Axial indications at support plates	257
Circumferential indications at support plates	212
Other	19
TOTAL	527

The SG tube bundle integrity was reestablished by plugging each of the above 527 tubes and by installing stabilizers in these tubes as necessary. Tube stabilization criteria were developed based on analysis of the maximum crack arc-lengths which could be allowed, such that circumferential cracks would not propagate by fatigue to the point of complete severance of the tube subsequent to plugging. These analyses considered axial loadings on the plugged tubes due to heatup/cooldown cycles (assuming the tubes are dented at the tube support plates) and flow induced vibration loadings.

The second half of the current fuel cycle is planned for 252 estimated full power days (EFPD), while the first half of the operating cycle was 254 EFPD in duration. Since the length of these two periods are relatively equal, the eddy current (EC) inspection results at the end of the second half of the cycle (January 1993) could be expected to be comparable to those observed during the previous inspection (February 1992) with respect to the number and size of indications. Comparable inspection results would be expected to be obtained assuming that both the inspection methods and the operating conditions (T-hot) are the same for both halves of the cycle. However, the licensee expects that both the number and size of the indications at the end of the second half of this fuel cycle will be less than that found during the mid-cycle inspection due to the following considerations:

- Operation at a lower power level during the second half of the cycle with a EOC power coastdown. The lower power level is expected to result in approximately a 7% reduction in the number of newly initiated cracks and in the growth rates of existing cracks (cracks that were below detection thresholds at the February 1992 inspection).

- Performance of a first time full RPC inspection at the TSP locations. The RPC "inspection transient" (initial application of more restrictive eddy current analysis guidelines or the use of the more sensitive RPC probe at tube diametral changes such as dented intersections) at the TSP intersections is expected to lead to a reduction in the number and size of indications at the end of the second half of the operating cycle. An 8% reduction in the crack angle of circumferential indications and a one-third reduction in the number of indications is expected to occur from this inspection transient.

The licensee has also stated that newly initiated indications are not a significant concern for tube integrity in the current half of the operating cycle, but that the indications already present, but below detection thresholds, and their growth over the current half of the operating cycle are the most important.

To demonstrate compliance with the structural performance criteria contained in Regulatory Guide 1.121 for this half of the operating cycle, the licensee presented arguments in the March 2, 1992 meeting that since all indications found during the mid-cycle SG tube inspection (February 1992) were within structural performance criteria contained in Regulatory Guide 1.121, then all indications in January 1993 will be within the structural performance criteria of Regulatory Guide 1.121. In the licensee's May 1, 1992 submittal,

additional data was provided to demonstrate that the end-of-cycle indications for all known modes of SG tube degradation observed at North Anna Unit 1 would be within the structural performance criteria of Regulatory Guide 1.121.

Compliance with Regulatory Guide 1.121 for single circumferential cracks at both the WEXTEX transition and the TSPs is ensured by the following. No single circumferential indications at the WEXTEX transitions that exceeded the limiting crack size with respect to meeting the structural performance criteria in Regulatory Guide 1.121 were found during the mid-cycle inspection (December 1991). With the exception of two single circumferential crack indications at the TSP area, the "as-found" crack indications at the TSPs were determined to be less than the limiting crack sizes for meeting the structural performance criteria in Regulatory Guide 1.121. The licensee and Westinghouse believe the two exceptions at the TSP elevation will not recur in January 1993 since tubes inspected after the first half of the operating cycle (February 1992) were inspected with a more sensitive probe (RPC), with a lower threshold of detection than the probe used during the previous inspection (8x1 probe). Reexamination of the previous 8x1 and RPC probe data indicates that many of the circumferential cracks now being detected at the TSPs with the RPC probe were present during the previous refueling outage but were below detection thresholds although they can be detected with hindsight. Furthermore, the licensee and Westinghouse conclude that the tubes meet the structural margins required in Regulatory Guide 1.121 since the cracks are not entirely through-wall and that the deepest part of the cracks are only a fraction (40%-60%) of the total crack angle measured. The licensee has provided data that suggests that even if the two single circumferential indications which exceeded the limiting crack size for meeting the structural criteria in Regulatory Guide 1.121 were entirely through-wall, the 8% reduction in crack angle due to the RPC "inspection transient" and the 3 degree reduction in crack angle due to reduced temperature considerations would result in an expected EOC crack angle less than the limiting crack angle.

Several axial indications extending beyond the TSP area were observed and plugged during this inspection outage. The lengths of these cracks above and below the TSP were considered for tube burst and leakage evaluation since the extensive denting at the TSPs is considered to prevent axial cracks that are within the confines of the TSPs from opening. The axial crack lengths of these indications, as measured by RPC, were less than the limiting crack size for meeting the structural performance criteria contained in Regulatory Guide 1.121 assuming that the crack is segmented (small ligaments in the axial crack network). The presence of ligaments in the axial crack networks is based on a pulled tube analysis from North Anna Unit 1. The maximum axial crack length observed was within the Regulatory Guide 1.121 criteria for burst at steam line break differential pressures assuming non-segmented cracks. Since the size of these axial indications were less than the limiting crack size required to meet Regulatory Guide 1.121 structural performance criteria, the licensee and Westinghouse expect that the axial cracks at the end of next cycle will be within these criteria.

Multiple circumferential indications were observed at both the WEXTEX transition area and the TSP areas during the February 1992 outage. These indications are typically composed of two circumferential cracks separated by a ligament (non-cracked portion of the tube wall). The licensee and Westinghouse presented arguments that all of the multiple circumferential indications at both the WEXTEX transition and the TSPs met the structural performance criteria contained in Regulatory Guide 1.121 since each had a ligament that exceeded the minimum ligament size required to meet the three-times-normal operating pressure differential burst capability limit.

Fourteen occurrences of mixed-mode cracking (axial and circumferential cracks at the same TSP) were observed during this inspection. Of these 14 mixed-mode cracks, only 7 had both circumferential and axial cracks at the same edge of the TSP. The licensee and Westinghouse claim that a ligament of approximately 3-wall thicknesses (approximately 20 degrees) is sufficient to ensure that the burst pressure of mixed-mode cracked tubes can be evaluated assuming non-interacting cracks. Since the axial lengths of the tubes with mixed-mode cracking were within structural limits and the minimum ligament was greater than or equal to 20°, the licensee and Westinghouse conclude that these tubes met the structural limits of Regulatory Guide 1.121.

The licensee divided the WEXTEX transition and TSP cracks found during this inspection outage into four zones for determining their susceptibility to tube vibration. The licensee claims that only two tubes in zone 1 (the peripheral zone) contained indications that exceeded the minimum through-wall crack angle required for crack propagation due to tube vibration. All other tubes with indications, regardless of zone, had crack angles less than that required for crack propagation due to tube vibration. Of the two tubes in zone 1 whose crack angles were in excess of the through-wall crack angle required for crack propagation due to tube vibration, one was located at the TSP while the other was located in the WEXTEX transition area. The licensee and Westinghouse conclude that the deepest part of both of these cracks was less than that required for crack propagation due to tube vibration and therefore, no WEXTEX or TSP crack indications are subject to crack propagation due to tube vibration. In addition, if the actual location of these cracked tubes within the zone is taken into consideration, a greater margin between the maximum acceptable crack angle and the observed crack angle is obtained.

In summary, the crack distributions expected at the end of the second half of the operating cycle, based on operating cycle considerations and inspection transient considerations, are based on modifying the mid-cycle distributions as follows:

WEXTEX Circumferential Indications
- reduction in crack angles by 3°
- no change in the number of indications

TSP Circumferential Indications
- reduction in crack angles by both 3° and 8% of the last inspection results
- number of indications reduced to 2/3 of last inspection

TSP Axial Indications
- no change in crack length
- number of indications reduced to 2/3 of last inspection

The Technical Specifications for North Anna Unit 1 incorporate a very tight limit (i.e. 100 gpd) on allowable primary-to-secondary leakage. In addition, the licensee plans to continue to adhere to an administrative limit of 50 gpd. As has been noted by the staff in previous safety evaluations, the staff considers the licensee's program for monitoring primary-to-secondary leakage to be very effective in terms of its ability to alert the operators in a timely manner to an increasing trend in primary-to-secondary leakage. The licensee's program includes the use of N-16 monitors which allows for continuous monitoring in the control room of primary-to-secondary leakage. The program also includes use of all primary-to-secondary leak detection instrumentation in determining whether or not the Technical Specification limits on leakage have been exceeded. Primary-to-secondary leakage during the first half of the operating cycle (prior to the mid-cycle inspection) was relatively low, with typical leakage less than 10 gallons-per-day per SG.

3.0 CONCLUSION

The staff concurred with the licensee's conclusion that the SGs had been restored to an operable condition and that restart from the mid-cycle outage posed no undue risk to the public health and safety. This conclusion was based on the preliminary review of the technical data presented to the NRC staff by the licensee and Westinghouse on March 2, 1992 at NRC headquarters. A review of the report submitted by the licensee by letter dated May 1, 1992, further demonstrates, by providing a quantitative assessment of the benefits from operating at reduced power and from performing a more detailed eddy current inspection, that the SGs have been returned to an operable condition and that operation through January 1993 poses no undue risk to the public health and safety.

The extensive SG inspection activities and the stringent primary-to-secondary leakage monitoring program (and the associated leakage limits) provide further assurance that the unit can be safely operated through January 1993.

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