VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

June 27, 1995

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 95-239
NL&P/JBL R0
Docket Nos. 50-280
50-281
50-338
50-339
License Nos. DPR-32
DPR-37
NPF-4
NPF-7

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNITS 1 AND 2
NORTH ANNA POWER STATION UNITS 1 AND 2
RESPONSE TO NRC GENERIC LETTER 95-03
CIRCUMFERENTIAL CRACKING OF STEAM GENERATOR TUBES

By letter dated April 28, 1995, the NRC issued Generic Letter 95-03, "Circumferential Cracking of Steam Generator Tubes," notifying addressees about the safety significance of recent steam generator tube inspection findings. The generic letter requested an evaluation of recent operating experience with respect to the detection and sizing of circumferential indications to determine applicability and susceptibility of our plants to this type of cracking, development of a site-specific safety assessment to justify continued operation until the next scheduled steam generator tube inspections, and development of steam generator tube inspection plans for the detection of circumferential cracking. Virginia Electric and Power Company has performed the requested actions of the generic letter. The attachment to this letter provides the requested safety assessment and inspection plans for Surry and North Anna Power Stations.

If you have any further questions, please contact us.

Very truly yours,

RF Saunders

James P. O'Hanlon
Senior Vice President - Nuclear

Attachment

A001

cc: U.S. Nuclear Regulatory Commission
Region II
101 Marietta Street, N.W.
Suite 2900
Atlanta, Georgia 30323

Mr. M. W. Branch
NRC Senior Resident Inspector
Surry Power Station

Mr. R. D. McWhorter
NRC Senior Resident Inspector
North Anna Power Station

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by R. F. Saunders, who is Vice President - Nuclear Operations, for J. P. O'Hanlon who is Senior Vice President - Nuclear, of Virginia Electric and Power Company. He is duly authorized to execute and file the foregoing document in behalf of that Company, and the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 27TH day of June, 1995.

My Commission Expires: May 31, 1998.

Vicki L. Hull
Notary Public

(SEAL)

Response to NRC Generic Letter 95-03
Circumferential Cracking of Steam Generator Tubes
For Surry and North Anna Power Stations

1.0 Introduction

Recent nondestructive examination (NDE) of the steam generator tubing at the Maine Yankee Nuclear Plant identified a large number of circumferential indications at the top of the tubesheet region. These most recent inspection findings coupled with previously documented inspection results regarding circumferential cracking led to the issuance of NRC Generic Letter 95-03, "Circumferential Cracking of Steam Generator Tubes" on April 28, 1995. The information detailed herein addresses the requested actions of the Generic Letter 95-03 as they pertain to Westinghouse designed and manufactured steam generators in general and to Surry Units 1 and 2 and North Anna Units 1 and 2 in particular.

The most recent inspection findings concerning steam generator tube expansion regions (Maine Yankee and Arkansas Nuclear One Unit 2) appear to have impacted those steam generators utilizing the Combustion-Engineering (C-E) EXPLANSION process. Similarly, though to a lesser degree, tubes expanded using the Westinghouse WEXTEX process have been affected by circumferential cracking.

Successive inspection results using rotating pancake coil (RPC) probes for Westinghouse plants with hardrolled or explosively expanded tubes have indicated steadily declining numbers of new indications, declining angular extent and very low growth rates. In addition, domestic inspection experience with hydraulically expanded tubes has not identified circumferential cracking in thermally treated Inconel tubes. The Surry and North Anna steam generators are included in this latter group.

Furthermore, the reported sludge pile height at Maine Yankee (up to 18 inches) may have influenced indication detectability. Such sludge pile thicknesses are not representative of operating conditions in the Surry or North Anna steam generators.

1.1 Historical Circumferential Degradation Locations

Available historical information shows that, for some Westinghouse plants, circumferential cracking has been detected in the tubesheet region at the tube expansion transitions from expanded to unexpanded tube, at the Row 1 and 2 U-bend tangent points, and at dented tube support plate intersections.

1.2 Circumferential Degradation Evaluation of Small Radius U-bends and TSPs

The incidence of circumferential indications at the Row 1 and 2 U-bend tangent points has not been significant in either number of indications or indicated RPC angles. However, some plants have decided to preventively plug the Row 1 tubes and, in other plants, the tubes in Rows 1 and 2. Additionally, some plants have applied U-bend

heat treatment in this region and have effectively recovered tubes previously preventively plugged. The Surry and North Anna replacement steam generator tubes were stress relieved after bending during their fabrication to reduce the potential for stress-related cracking.

A leakage event occurred in 1987 at North Anna which resulted in a steam generator tube rupture due to high cycle fatigue at a dented top tube support plate. Pursuant to NRC Bulletin 88-02, the domestic Westinghouse steam generators with carbon steel tube support plates have been analyzed for the potential to experience high cycle fatigue at this location with a methodology accepted by the NRC. In cases where the analysis indicated that fatigue usage could exceed 1.0, the tube was either plugged and stabilized or plugged using a leak limiting sentinel plug. Three conditions must be present for high cycle fatigue at the top tube support plate: denting, lack of anti-vibration bar (AVB) support, and locally elevated steam velocities due to non-uniform AVB insertion depths. In addition, denting at tube support plate (TSP) intersections, even when not subject to high cycle fatigue, has caused circumferential cracking. However, the Surry and North Anna replacement steam generators, with quatrefoil broached tube holes in stainless steel tube support plates, are not expected to experience denting or circumferential cracking which may result from denting.

In many Westinghouse units where the tube material and/or expansion process warrant, an augmented top of tubesheet region inspection program is conducted on a cycle to cycle basis. Many Westinghouse plants have had all hot leg tubes inspected at the top of tubesheet region using the RPC probe and continue to do so on a cycle to cycle basis. Currently available probes, coupled with properly implemented analysis criteria and techniques, have been demonstrated to be sufficient to identify circumferential indications in the tubesheet region.

Collectively, the items discussed above and further detailed on the following pages provide justification for the continued operation of Surry Units 1 and 2 and North Anna Units 1 and 2.

2.0 Operating Experience with Circumferential Cracking for the U.S. Population of Westinghouse Steam Generators

Surry Units 1 and 2 use Westinghouse Model 51F steam generators and North Anna Units 1 and 2 use Westinghouse Model 54F steam generators. The steam generators at Surry Units 1 and 2 use Alloy 600 thermally treated (TT) tubing and North Anna Units 1 and 2 use Alloy 690 TT tubing. The nominal tube is 0.875 inch OD x 0.050 inch nominal wall thickness for each of the Surry and North Anna steam generators. The listings of plants with steam generator types using a similar hydraulic tube expansion process as used in the Surry and North Anna steam generators are provided in the following tables. The information presented was provided by Westinghouse Electric Corporation in support of WOG utilities' responses to the subject generic letter.

Hydraulically Expanded Plants Alloy 600 Thermally Treated (TT) Tubing				
Plant/Steam Generator Model	Startup	First Time Circ. Cracking	Location	Tube Pull and Results
Braidwood Unit 2 / D5	1988	None	N/A	N/A
Byron Unit 2 / D5	1987	None	N/A	N/A
Callaway (a) / F	1984	None	N/A	N/A
Catawba Unit 2 / D5	1986	None	N/A	N/A
Comanche Peak 2 / D5	1993	None	N/A	N/A
Millstone Unit 3 / F	1986	None	N/A	N/A
Point Beach Unit 1 (b) / 44F	1984	None	N/A	N/A
Robinson Unit 2 (b) / 44F	1984	None	N/A	N/A
Seabrook / F	1989	None	N/A	N/A
Surry Unit 1 (b) / 51F	1981	None	N/A	Yes, no SCC found, indication attributed to probe liftoff, tube geometric effects
Surry Unit 2 (b) / 51F	1980	None	N/A	N/A
Turkey Point Unit 3 (b) / 44F	1982	None	N/A	N/A
Turkey Point Unit 4 (b) / 44F	1983	None	N/A	N/A
Vogtle Unit 1 / F	1987	None	N/A	N/A
Vogtle Unit 2 / F	1989	None	N/A	N/A
Wolf Creek / F	1985	None	N/A	N/A

(a): Rows 1 thru 10 are Alloy 600 TT only
(b): Replacement Steam Generators

Hydraulically Expanded Plants Alloy 690 Thermally Treated (TT) Tubing				
Plant / Steam Generator Model	Startup	First Time Circ. Cracking	Location	Tube Pull and Results
Cook Unit 2 (a) / 54F	1989	None	N/A	N/A
Indian Point 3 (a) / 44F	1989	None	N/A	N/A
North Anna Unit 1 (a) / 54F	1993	None	N/A	N/A
North Anna Unit 2 (a) / 54F	1995	None	N/A	N/A
V. C. Summer (a) / Δ75	1994	None	N/A	N/A

(a): Replacement Steam Generators

3.0 Safety Assessment

3.1 Alloy 600 TT and Alloy 690 TT Tubing Integrity

Thermally treated Alloy 600 tubing represents a major step in the evolution of progressively optimized corrosion resistant tubing materials. EPRI Report NP-3501, "Optimization of Metallurgical Variables to Improve Corrosion Resistance on Inconel Alloy 600," shows the distinct advantages of Alloy 600 TT over Alloy 600 mill annealed (MA). Data contained in this report shows minimal stress corrosion cracking (SCC) in Alloy 600 TT c-rings at 600°F in caustic solutions (10% NaOH). Crack depths were generally 2.5 to 4.5 times less than Alloy 600 MA at 600°F. Primary water stress corrosion cracking (PWSCC) initiation times were also found to be greater for Alloy 600 TT versus Alloy 600 MA. Also, no SCC was detected in Alloy 600 TT small radius U-bends tested at 680°F. This report also showed a dependence upon residual stress level and crack growth rate and initiation times. Westinghouse data has shown that the stress levels in hydraulically expanded tubing are less than the associated levels in either explosively or mechanically expanded tubes. Also, some plants, including Surry, utilizing Alloy 600 TT (with hydraulic expansion) operate at significantly lower temperatures, about 15 to 20 degrees lower, than the plants with Alloy 600 MA hydraulically expanded tubing. Since corrosion rate is temperature dependent, a lesser potential for rapid corrosion is expected.

Alloy 690 TT tubing represents a further advancement in the evolution of progressively optimized corrosion resistant tubing materials. Testing programs have indicated that Alloy 690 TT tube material provides for significant PWSCC resistance and increases in outside diameter stress corrosion cracking (ODSCC) resistance, compared to Alloy

600 TT. Alloy 690 TT is generally accepted as the currently available steam generator tube material of choice. Alloy 690 TT tubing has been in service at Cook Unit 2 since 1989 with no reported instances of localized tube wall degradation. Westinghouse Alloy 690 TT sleeves have been in service since 1983. There has been no reported degradation in these sleeves.

3.1.1 Pulled Tube Examination Results

In 1990, two tubes, R10C53 and R25C57, were pulled from the Surry Unit 1 replacement steam generators (Alloy 600 TT tubing). Field NDE results suggested the presence of circumferentially oriented degradation. Upon further review, it was concluded that the poorly defined RPC signal for R10C53 was similar to that of a "ding" or mechanical deformation. A 70° "groove", mechanical in nature, was found in R25C57 on the tube OD and attributed to the interaction of the tube with the edge of the tubesheet during the expansion process. Although, the hydraulic expansion process used was designed to locate the transition slightly below the top of the tubesheet, it has been concluded that R25C57 tube was overexpanded above the top of the tubesheet.

Destructive examination of the pulled tube segments detected no corrosion, either ID- or OD-initiated. The source of the NDE indications was determined to be attributed to probe liftoff in the expansion transition and mechanical conditions in the tube resultant from the tube installation process.

3.1.2 EOC Structural Limit Crack Angle Calculations

No detectable circumferentially-oriented degradation has been evidenced at domestic plants utilizing thermally treated tube material and the hydraulic expansion process. Based on the extended plant operational periods to date, which extend from 1980, it is unlikely that rapid tube degradation in the expansion transitions in these plants would occur prior to the next scheduled tube inspection or on a cycle to cycle basis in the near future. End of cycle (EOC) structural limits for 7/8 inch OD Alloy 600 TT tubing would be consistent with the available data developed initially for WEXTEX plants. Despite the fact that no circumferential degradation has been detected in these units, EOC structural limits are provided below for completeness.

To permit a rapid scoping assessment for tube burst capability of circumferential indications, a burst correlation was developed for throughwall circumferential indications. The burst correlation was then applied to define the structural limit on throughwall crack angles that satisfy the Regulatory Guide 1.121 burst margin for three times normal operating pressure differential. If measured RPC crack angles, after reduction for coil lead-in and lead-out effects (about 30°) for throughwall indications, are less than the structural limit, it can be readily concluded that the indications satisfy burst margin guidelines. If the measured RPC angles exceed the assumed throughwall structural limit, additional inspection (such as UT) or structural analysis is

needed to assess structural integrity. This section describes the development of the throughwall crack angle structural limit.

Utilizing the burst correlation developed from test data using electric discharge machining (EDM) flaws and analytical models, the structural limits for throughwall circumferential indications were developed as given for the crack models in the following tables. The burst pressure data were adjusted to account for lower tolerance limit material properties.

7/8 Inch Tubing EOC Structural Limits for Circumferentially Oriented Degradation			
	Single Throughwall Crack Model	Single Throughwall Crack with 50% Degraded Ligament	Segmented Throughwall Crack Model
3ΔP = 4500 psi	210°	210°	264°
3ΔP = 4300 psi	226°	226°	269°
SLB ΔP = 2560 psi	321°	283°	318°

11/16 inch Tubing, EOC Structural Limits for Circumferentially Oriented Degradation	
	Single Throughwall Crack with 50% Degraded Ligament
3ΔP = 3750 psi	247°
SLB ΔP = 2560 psi	283°

The single throughwall crack model is applicable to both ID or OD degradation. The segmented model is more typical of PWSCC. The throughwall plus 50% deep model was developed to represent 360° indications found for ODSCC.

Therefore, a single, uniform throughwall crack of 247° with 50% deep OD degradation existing over the remaining 113° tube arc would satisfy the Regulatory Guide 1.121 3ΔP burst recommendations while a 283° throughwall crack with 50% deep OD degradation existing over the remaining arc would have a predicted burst pressure of 2560 psi for 11/16 inch OD tubing. Most likely, based on the industry accepted detection thresholds for circumferential cracking, this type of indication, if encountered in the field, would produce an RPC crack angle of nearly 360°.

Additionally, it is expected that throughwall cracks of this size would experience primary to secondary leakage, alerting the plant operators of the tube condition. Such was the case for the McGuire kinetically welded sleeve leakage events. In both cases, the leakage was able to be trended and readily detectable. The crack morphology of these cracks was more that of single uniform cracks since the morphology was driven more by high residual stress than by intergranular corrosion.

Based on the developmental work done for 7/8 inch tubing, the corresponding crack lengths for single uniform throughwall cracks without additional degradation in the remaining ligament would be consistent at the 3ΔP condition and greater than 283° for 11/16 inch OD tubing at a SLB ΔP of 2560 psi. Based on the similarity of the limiting crack angles for the two tubing sizes, the limiting single throughwall crack angle which would support a burst capability of 2560 psi would extrapolate to approximately 310° to 320°.

3.1.3 Inspection Methodology

Personnel qualified (to the extent available) to Appendix G of the EPRI Guidelines and eddy current techniques meeting the intent of Appendix H of the EPRI Guidelines have been utilized for steam generator inspections for detection of circumferential indications at the top of the tubesheet (TTS) at Surry Units 1 and 2. Site specific examinations are administered to eddy current data analysts prior to the start of inspection activities.

Since the Spring of 1993, the Surry TTS inspection program has included examination of approximately 3% of the total number of tubes (i.e., 301 tubes) in that unit each refueling outage. This sample is focused in the sludge pile area in the center of the tube bundle where SCC would be expected to initially occur. One steam generator is opened for examination each refueling outage on a rotating basis. This TTS inspection program utilizes the RPC probe for detection of circumferentially-oriented indications.

The RPC examinations performed at Surry Units 1 and 2 to date have not identified any circumferential cracking. The reaffirmation of the detection capabilities of conventional MRPC probes by the EPRI NDE Center further supports the conclusion that the inspections performed to date have provided an adequate assessment of the structural integrity of the steam generators.

3.1.4 Surry and North Anna Tube Integrity Assessments

The past three most recent steam generator inspections at Surry Power Station were performed consistent with the EPRI and industry guidelines regarding calling criteria. These inspections did not identify a degradation mechanism that could cause circumferential indications. In addition, the 1990 inspection program at Surry Unit 1 resulted in an inspection at the top of tubesheet using the RPC probe in 100% of the

available tubes in the three steam generators. As described above, this inspection resulted in two tubes being pulled for examination with no evidence of degradation found.

The North Anna Units 1 and 2 steam generators were replaced in 1993 and 1995, respectively. Based on the limited time in operation since replacement, the enhanced corrosion-resistant performance of Alloy 690 TT tubing, and the lower-stresses induced by the full-depth hydraulic expansion process, the possibility of circumferential cracking in the North Anna Units 1 and 2 steam generator tubes is considered to be negligible.

Furthermore, there have been no domestically reported instances of circumferential degradation in the hydraulic expansion transitions of thermally treated tubing. However, for the sake of completeness, postulated EOC circumferential crack angles were considered. Postulated EOC crack angles would be projected to be well below the EOC structural limits for single or single throughwall cracks with 50% degradation in the remaining ligament, as listed in Section 3.1.2 of this response. Since there is no domestic operating experience of circumferential indications in full depth hydraulically expanded plants with Alloy 600 TT or Alloy 690 TT tubing, it is reasonable to assume that growth rates of postulated circumferential indications are negligible. In fact, based on the currently available data, it would be considered quite conservative to assume growth rates of any value. When considering the negligible growth rates and factoring in industry accepted detection thresholds for throughwall circumferential degradation, no crack indications would be expected at the end of the current operating cycles at either Surry or North Anna which would challenge tube integrity. Similarly, tube structural integrity would be expected to be maintained during the next several operating cycles considering the historical performance of these expansions, and assuming that plant operating parameters are not significantly altered from current conditions.

3.2 Assessment Conclusion

Plants with Alloy 600 TT tubing utilize full depth hydraulic expansion. The apparent lack of susceptibility to rapid degradation of hydraulically expanded Alloy 600 MA tubing is confirmed by the operating experience of a plants with Model E and Model F steam generators. Domestic plants with Alloy 600 TT tubing have been operating since 1980 with no reports of corrosion degradation. Plants with Alloy 690 TT tubing also utilize full-depth hydraulically expanded tubing. Plants with Alloy 690 TT tubing have been operating since 1989 with no reports of corrosion degradation. Furthermore, Alloy 690 TT tubing has been shown by extensive testing programs to represent the current state-of-the-art in corrosion resistant steam generator tubing material. There are no operating experiences, test programs, or other suspected outside considerations which would indicate that rapid corrosion degradation of Alloy 600 TT tubing or Alloy 690 TT tubing would be experienced, either up to the end of the current operating cycles for these units, or during any cycle in the near future.

4.0 Inspection Plans

Surry Units 1 and 2 plan to continue with the top of tubesheet inspection program described in Section 3.1.3 above. This inspection will include examination of 301 tubes in the inspected steam generator during the next refueling outage for each unit. North Anna plans to conduct a top of tubesheet inspection program during the next refueling outage for each unit. This inspection will include examination of 324 tubes using examination techniques and equipment capable of detecting circumferentially-oriented indications in the expansion transition region. Personnel qualified to EPRI Guidelines, Appendix G, and eddy current techniques using the guidance of Appendix H of the EPRI Guidelines will be utilized for these steam generator inspections.

5.0 Summary

Virginia Electric and Power Company has reviewed the applicable industry operating experience regarding circumferential cracking of steam generator tubes and has assessed the potential impact on operation of the Surry and North Anna steam generators. Based on industry operating experience with Alloy 600 TT and Alloy 690 TT tubing using full-depth hydraulic tubesheet expansion in combination with the eddy current inspection experience at Surry and the recent replacement of the North Anna steam generators, we conclude that the Surry and North Anna steam generators do not contain degradation which would compromise the integrity of the tubing during their current operating cycles.

The above safety assessment, review of past inspection results, and devepment of future inspection plans for the top of tubesheet region of the Surry and North Anna steam generators fully respond to the NRC's concerns associated with circumferential cracking of steam generator tubes as expressed Generic Letter 95-03.