Consumers Power

POWERING MICHIGAN'S PROGRESS

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DOCKET 50-255 - LICENSE DPR-20 - PALISADES PLANT -
STEAM GENERATOR TUBE STABILIZATION EVALUATION (TAC #71851)

Consumers Power Company has discussed the issue of steam generator tube stabilization with the NRC Staff on a number of occasions. During a conference call on December 22, 1988, the NRC Staff sought assurance from Consumers Power Company that we had thoroughly reviewed recent steam generator tube damage and could conclude from the data that no immediate additional tube plugging, stabilizing or other repair or inspections were required.

The NRC Staff is aware of at least one instance at another unit (Ginna) where failed plugged tubes have in turn caused failure of active tubes. The NRC Staff encouraged Consumers Power Company to review our steam generator data, confer with outside consultants with experience in tube stabilization and understanding of past failures, and to establish confidence that a long-term approach to steam generator tube integrity is adequate.

By letter dated December 23, 1988, Consumers Power Company committed to respond in writing to NRC Staff concerns by January 31, 1989. The written response was intended not only to indicate why short-term action is not required, but also to establish a plan as to how Consumers Power Company expects to proceed, in the long-term, with respect to the tube stabilization aspects of the steam generator tube stability issue. The attached evaluation report provides the requested information.

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Palisades is currently shut down to investigate a tube leak in the B steam generator. Information gained from the results of this investigation may provide additional insight relative to the tube stabilization issue. If needed, this evaluation will be revised accordingly.

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Attachment

ATTACHMENT

Consumers Power Company
Palisades Plant
Docket 50-255

STEAM GENERATOR TUBE STABILIZATION EVALUATION REPORT

January 31, 1989

6 Pages

OC0189-0024-NL02

STEAM GENERATOR TUBE STABILIZATION EVALUATION REPORT

I. HISTORY

In December 1987, Palisades shut down due to a steam generator (S/G) tube leak in Quad 2, Line 35, Row 122 of the B S/G . The crack causing the leak was approximately 85 degrees in circumferential extent located near the lower edge of Support Plate 13. Eddy current inspection (utilizing 4C4F, 540 SFW and 540F techniques) of 40 tubes surrounding the leaking tube detected no additional crack-like indications.

In August 1988, Palisades again came down due to a steam generator tube leak. The leaking tube was in Quad 2, Line 33, Row 122 of the B S/G. The crack was approximately 57 degrees in circumferential extent located near the lower edge of Support Plate 13. This tube had been inspected in the December 1987 S/G inspection, but no detectable indications had been present in the tube (the 4C4F technique is qualified to detect cracks greater than or equal to 40% thru-wall).

Subsequent eddy current testing with the motorized rotating pancake coil probe (MRPC) and the 4C4F probe in B S/G at Support Plate 13 detected eight additional crack-like indications. Of these eight indications, six were not detectable with the 4C4F technique. All of the six are considered to be very small circumferentially (estimated to be 29 degrees circumferential or less) and below the 4C4F 40% thru-wall detectability limit. In addition, the true nature of three of the six was somewhat ambiguous in that the MRPC may have actually been responding to deposits or dents. The eight tubes are as follows:

Quad	Line	Row	Description
2	30	123	Detected With MRPC
2	30	125	Detected With MRPC (Conservatively Plugged)
2	31	120	Detected With MRPC (Conservatively Plugged)
2	31	122	Detected With MRPC and 4C4F
2	31	128	Detected With MRPC
2	36	123	Detected With MRPC
2	40	123	Detected With MRPC (Conservatively Plugged)
3	37	120	Detected With MRPC and 4C4F

On December 5, 1988 while returning to full power from the August, 1988 shut down, Palisades came off line as a result of a weld defect in the tube plug located in Quad 2, Line 31, Row 122 of the B S/G. This tube had been plugged in the August inspection for a circumferential crack indication of approximately 34 degrees located near the lower edge of Support Plate 13. At the time of plugging this indication had not been leaking. Eddy current inspection, in December 1988, with the 4C4F probe showed the signal had grown in prominence since the August 1988 inspection (inspection with the MRPC was not possible).

To determine if additional degradation had occurred in surrounding tubes, more eddy current testing was performed. The MRPC was used to inspect 80 tubes in each corner of Support Plate 13 in Quads 2 and 3 at the 13th support plate of the B steam generator. In addition, 79 tubes were inspected in Quad 1 and 55 tubes in Quad 4 in this same area of Support Plate 13. The results of the hot leg testing showed no additional increase in degradation. One tube in the cold leg, Quad 4, Line 36, Row 127 was found to contain a crack-like indication. This tube had not previously been inspected with the MRPC probe.

Three additional tubes which contained somewhat ambiguous signals at Support Plate 13 were plugged electively. It is not certain if the MRPC was actually responding to deposits or dents, or to the early stages of crack initiation. The three tubes electively plugged are:

Quad	Line	Row
3	34	121
4	31	124
4	35	126

In conjunction with the eddy current testing, Palisades deplugged the December 1987 leaker, tube location, Quad 2, Line 35, Row 122 of the B S/G. This tube was deplugged in order to provide information on the progression of degradation in the tube during the year the tube was out of service. The MRPC results indicated the thru-wall crack at Support Plate 13, for which the tube was plugged, had changed significantly. The original 85 degree circumferential crack had grown to approximately 206 degrees and a second crack of approximately 244 degrees had formed at the center of Support Plate 13. All of the active tubes surrounding this tube were electively plugged.

II. ANALYSIS PERFORMED

To address Consumers Power Company and NRC Staff concerns with regard to plugged tube stability and the need for tube stabilization, steam generator data was discussed with two NSSS vendors who are familiar with the nature of the plugged tube failures at other facilities. The similarities and differences between the thermal hydraulic and structural environments associated with those events were reviewed in terms of the Palisades information as determined from recent testing. An assessment of the structural characteristics of limiting plugged tubes (ie, most susceptible to circumferential cracking) in the Palisades steam generator was conducted.

Our understanding is that one of the documented plugged tube failures (Ginna) occurred near the tube sheet. The failure occurred in a high cross flow and high fluid density environment. A number of tubes were contacted due to a rotary-type motion of the failed tube. The high fluid density/high flow environment provided large impacting forces over large tube areas.

In another documented tube failure (North Anna), the failure occurred high in the steam generator in the bend region. In this instance, the ends of the tube were severely dented which would imply a relatively stiff (fixed) tube-end boundary condition. The tube did not realize any support between the fixed supports in the bend region which might be associated with batwings, antivibration bars etc. The tube length was relatively long between the fixed supports. For this case, the fixed boundary conditions implied little structural damping. The long tube span length implied a relatively low fundamental frequency. The lack of contact at intermediate span support provided no energy dissipation (damping) mechanism. The location of the tube provided a region of significant cross flow which implied a potential forcing function to excite a low frequency/lightly damped structural arrangement.

Our understanding of the Ginna and North Anna failures leads us to a determination that any quantitative assessment of tube stability requires addressing a specific tube:

- With dented boundary conditions
- With long unsupported length
- Located in a high cross flow region
- Located where significant crack growth has been detected.

The tube in Row 127, Line 35 was selected for assessment with regard to structural stability. This tube location was selected because it:

- Passes through Support Plate 13 where tube leaking appears to have originated in the recent past
- Does not realize support at Support Plate 14 above Plate 13

- Has the longest unsupported span length between Plate 13 and the vertical support V2

- Can be expected to see significant cross flow in the region of the tube segment.

It is understood that a number of tube support, tube length and cross flow velocity combinations exist which could be evaluated for stability in a vibrational environment. However, the tube segment that has been evaluated is judged to be as limiting as any other with regard to vibration stability. Is is also understood that a crack which may exist at the bottom edge of a support plate in the cold condition will be at that same location or higher (toward plate center) relative to the plate in the hot condition. Therefore, an evaluation of a failed tube with the failure just above Support Plate 13, Row 127, Line 35 is determined to represent a limiting assessment.

A finite element model of the tube was developed using a free boundary condition at the tube support plate and a fixed vertical support boundary condition. It was, therefore, assumed that the tube failed at the support plate. An intermediate batwing support was introduced into the model for out-of-plane (perpendicular to the tube geometry) response only. Fluid velocities and densities were developed based upon ATHOS results for the Fort Calhoun facility which is believed to closely characterize the Palisades thermal hydraulic environment. With these assumptions, the analysis methodologies of the past analyses for Palisades by Combustion Engineering and Westinghouse were revisited.

The results of the analyses implied that the frequency of the individual tube, with the assumption of the free support plate boundary condition is 10.6 HZ in-plane and 16.2 HZ out-of-plane. These frequencies were higher than those which would have been calculated for Ginna or North Anna with similar boundary conditions. This high frequency characteristic is due to the stiffness of the tube primarily because of its relatively short length; approximately four and a half feet.

For in-plane motion, a flow stability ratio of approximately 1.7 was calculated. The stability ratio represents the effective flow velocity over the tube segment divided by the critical velocity at which high amplitude vibration is possible. The stability ratio of 1.7 implies that the potential for relatively high amplitude vibration exists. This stability ratio is judged very conservative in that the friction in the batwing support which adds to vibration damping and thus increases the critical velocity has been ignored. However, before such vibration can develop, horizontal tube movement will result in contact of the failed tube with an adjacent vertical tube segment. Even if such contact did not take place, vertical contact of horizontal tubes will occur after closing of the a 0.50 inch initial tube-to-tube gap. Either type of contact will occur before the onset of high amplitude vibration and it will occur at a displacement less than that required to produce a failure due to cyclic bending stress at the fixed joint at vertical support V2. Failure stress acceptance is based on Combustion Engineering tests. The acceptability of the contact in either a local horizontal "kicking" mode of the failed end in-plane, or the bundle "slapping" action of parallel horizontal tube surfaces is not a catastrophic failure mechanism of the magnitude seen in the Ginna or North Anna failures.

The out-of-plane vibration response was characterized by a stability ratio of 0.40. This implies a very limited potential for high amplitude response. Thus, the swirling-type motion associated with at least one of the above referenced failures (Ginna) does not exist.

The Palisades plugged tubes are not judged to have significant potential for failing adjacent tubes even if it is postulated that the tube is failed at Support Plate 13. In general, this is because:

- The tubes are tightly confined by other tubes
- The tubes are relatively stiff which implies a relatively high natural frequency which in turn indicates a higher critical velocity
- Close contact in the batwing area provides a damping mechanism which also increases the critical velocity
- The fluid densities in the area, which are proportional to the hydraulic driving force, are low (about 25% of those at Ginna).

It is anticipated (although not proved) that some of the tube cracking detected, in both active and plugged tubes, is due to high tube stiffness induced by the locking of tubes in plates by denting and by the short tube lengths between supports. This stiffness can result in secondary stresses due to support plate growth or differential expansion between steam generator components. Whereas this stiffness can have a negative impact in terms of crack initiation, that same stiffness will tend to limit vibration response. The configuration of the Palisades steam generator bundle in the area of tube cracking is not judged vulnerable to flow-induced vibration for plugged tubes for the reasons noted above. Hence, no immediate action to stabilize tubes is required in the short-term.

III. ANALYSIS TO BE PERFORMED PRIOR TO 1990 S/G INSPECTION

Palisades previously committed (November 17, 1988 letter to NRC) to perform a crack stability/vibration assessment during 1989. This assessment is presently viewed as being developed along the lines of the recommendations associated with Regulatory Position C.3. of NRC Regulatory Guide 1.121.

In addition to the Regulatory Guide 1.121 discussion, the detailed long-term issue of plugged tube stabilization will be addressed. Limiting the scope of stabilization to a modest number of tubes will likely entail a review of the root cause for the leaks which have been discovered in the area of Support Plate 13. Therefore, it is the judgment of Consumers Power Company that a review of the need for a long-term stabilization program and a root cause assessment for existing cracked tubes is already embedded in the earlier Consumers Power Company commitments. It is requested that the submittal date for this analysis be extended to August 30, 1989.

IV. ACTIONS TO BE TAKEN BY CONSUMERS POWER COMPANY

In addition to performing the analysis discussed in Section III, Consumers Power Company intends to do the following:

1. Reinspect three of the four tubes in B steam generator which contain the largest circumferential cracks at Support Plate 13 and plug all surrounding active tubes in the current steam generator outage. The tubes are as follows:

Quad	Line	Row	Description
2	35	122	December 1987 Leaker
2	33	122	August 1988 Leaker
2	31	122	December 1988 Leaker*
3	37	120	Detected With Both MRPC and 4C4F

*(tube can't be accessed from hot leg due to stuck plug and will not be inspected this outage)

2. Deplug and reinspect all tubes in the B steam generator plugged for cracking at the 13th support plate on the hot leg side in the next scheduled steam generator inspection. Stabilization will be performed in accordance with the results of our previously committed to (November 17, 1988 letter to NRC) stabilization analysis which is to be performed prior to the next scheduled inspection.

3. Review all tubes plugged for cracking in A and B steam generator against the results of the stabilization analysis. Stabilize as determined appropriate during the next scheduled inspection.