NRC-99-085

Wisconsin Public Service Corporation
(a subsidiary of WPS Resources Corporation)
Kewaunee Nuclear Power Plant
North 490, Highway 42
Kewaunee, WI 54216-9511
920-388-2560

December 2, 1999

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

Ladies/Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Additional Information for Proposed Amendment 164 to the Kewaunee Nuclear Power Plant Technical Specifications: Extension of Use Through Cycle 24 of the Length Based Pressure Boundary Definition for Westinghouse Steam Generator Hybrid Expansion Joint Sleeved Tubes

Reference: 1) Letter from M.L. Marchi (WPSC) to Document Control Desk (NRC) dated June 22, 1999

In the reference Wisconsin Public Service Corporation submitted a proposed Technical Specification (TS) amendment. The amendment extends the use of the length based pressure boundary definition for Westinghouse steam generator hybrid expansion joint (HEJ) sleeved tubes through Cycle 24. During their review the NRC staff requested additional information regarding the submittal. The attachment to this letter contains the requested information.

In summary, taking into account the influence of both ligamentation and an interference lip in providing additional strength relative to the test configuration, the combined probability of any PTI not meeting RG 1.121 structural margins at the end of cycle 24 is on the order of 6.5×10^{-4}. Therefore, it is concluded that all PTIs left in service at the end of cycle 24 will meet RG 1.121 guidelines with regard to structural integrity.

Once again we would like to express our appreciation to the NRC staff for their timely review of this proposed TS amendment. We will continue to support this review effort by providing any needed additional information. Please contact Mr. Tim Olson of my staff at (920) 388-8443 if you have any questions or require additional information.

Sincerely,

Mark L. Marchi
Vice President–Nuclear

TPO
Attachment
cc - US NRC, Region III
US NRC Senior Resident Inspector
Electric Division, PSCW

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ATTACHMENT

Letter from Mark L. Marchi (WPSC)

To

Document Control Desk (NRC)

Dated

December 2, 1999

NRC RAI

Background

By letters dated May 14, July 3, August 27, and October 1, 1998, Wisconsin Public Service Corporation (WPSC) submitted for staff review a proposed technical specification (TS) amendment. The proposed amendment extends the use of the length based pressure boundary definition (L criterion) to disposition circumferential parent tube indications (PTI) in sleeved steam generator (SG) tubes that use the Westinghouse hybrid expansion (HEJ) joints. At the time, the staff determined that a small percentage of sleeved tubes having circumferential PTIs that are accepted for continued service under the L criterion may exhibit structural safety margins somewhat less than those in Regulatory Guide (RG) 1.121.

However, the staff found that the available test data and specimens incorporated conservatisms compared to actual field conditions. The specimens conservatively modeled 100 % throughwall and 360 degree in arc length flaws in the test tubes. The restraint of the tube support plates on the parent tube, which would provide additional structural support to the sleeved tube, was not considered in the tests. By letter dated October 2, 1998, the staff approved the L criterion but limited its application to cycle 23 only, considering that the growth of any potential PTI in one cycle would be unlikely to reach the size of the assumed worst-case flaw.

By letter dated June 22, 1999, WPSC proposed a technical specification amendment to extend the use of the L criterion through operating cycle 24. In order to continue its review, the staff has requested additional information.

The following provides the WPSC response to the staff RAI.

NRC Question 1

Provide a frequency distribution of the extent (arc length) of circumferential PTIs in the hybrid expansion joints from previous inspections.

WPSC Response to Question 1

The examination performed during the 1998 refueling outage (RFO), i.e., at the end of cycle (EOC) 22, was a "Go-No-Go" type of examination. The examination located the PTI relative to the TS defined pressure boundary without regard to circumferential extent (arc length) of the PTI. The 1998 inspection results reported PTIs as either 1) within, or 2) outside of the TS defined pressure boundary. No arc length was reported as part of the inspection record. As a result, the 1998 inspection data was sent to Zetec, Inc., for measurement of PTI arc lengths. Arc lengths were measured for all tubes with reported PTIs during the 1998 RFO under the L criterion. When reporting the indication, the peak-to-peak voltage was measured from the largest flaw response, and the circumferential extent (arc length) from the indication was measured in the MRPC window. The arc length measurement was taken from the point the indication left null to where it returned to null. The measurement encompassed the entire circumferential extent of the PTI, including all possible ligaments of the indication. In nearly all cases, individual bands of circumferential cracks could be identified. The reported PTI arc lengths are extremely conservative considering tube pull results from 1995 identifying considerable ligamentation of the PTI crack profile. It is also conservative in that the entire reported arc length is assumed to be 100% throughwall. WPSC's response to NRC Question 3 provides additional discussion on the effect of ligamentation on HEJ joint strength.

A total of 464 PTIs (338 tubes in SG A and 126 tubes in SG B) were reported during the 1998 RFO. PTI arc lengths were measured for 327 tubes in SG A and 125 tubes in SG B, representing 97.4% of the population. Arc lengths could not be measured for the remaining tubes due to problems encountered in recalling the data from the copy of the optical disc.

The distribution of PTIs from the 1998 inspection are grouped into three categories:

1) New PTIs with no detectable degradation reported from the 1996 RFO,

2) Existing PTIs left in service during cycle 22 via application of the delta-D (ΔD) criterion, and

3) Existing PTIs initially reported during the 1995 RFO and returned to service during the 1998 RFO via application of the L-criterion.

Table 1 provides the mean reported arc length, largest reported arc length, number reported during the 1998 RFO, and number currently in service for cycle 23 for each population of PTIs. The frequency distribution of PTIs from the 1998 inspection is provided in Figure 1 for SG A and Figure 2 for SG B.

Table 1

	PTIs with no previous degradation		Existing PTIs meeting the ΔD criterion		Existing PTI s returned to service during 1998 RFO	
	SG A	SG B	SG A	SG B	SG A	SG B
Mean Reported Arc Length (degrees)	120	89	251	195	199	171
Largest Reported Arc Length (degrees)	299	239	360	360	360	344
Number Reported during 1998 RFO	170	32	66	42	102	52
Number Remaining in Service for cycle 23	167	31	66	42	83	49

NRC Question 2

Provide an analysis of the circumferential PTI growth rate based on previous inspection data.

WPSC Response to Question 2

Growth rate information can be obtained from the following populations of tubes:

1) PTIs left in service following the 1996 RFO via application of the ΔD criterion (108 tubes), and

2) PTIs initially plugged during the 1995 RFO and returned to service during the 1998 RFO via application of the L criterion (154 tubes).

A total of 262 tubes are contained within these two populations. Arc lengths from the 1996 and 1995 inspection data were measured consistent with the methodology used in measuring arc lengths from the 1998 inspection data. Changes in arc lengths between the 1998 RFO and either the 1996 RFO or 1995 RFO were normalized in terms of arc length change per effective full power year (EFPY). A scatter plot showing the change in arc length per EFPY as a function of the initial PTI arc length is shown in Figure 3. The mean growth rate per EFPY is calculated in 30 degree bins, treating the negative arc length differences shown in Figure 3 as zero. The results are shown in Table 2. Similar growth rates were observed for both SGs, with higher growth rates per EFPY observed for the smaller arc lengths.

Table 2

PTI Arc Length Change per EFPY

Initial Arc Length Bin	Number of tubes			Mean Arc Length Increase (degrees)		
	SG A	SG B	Both	SG A	SG B	Both
30	0	0	0	NA	NA	NA
60	3	2	5	54	94	70
90	12	5	17	84	14	63
120	16	12	28	36	38	37
150	19	15	34	36	15	27
180	19	14	33	26	8	18
210	18	17	35	38	17	28
240	33	12	45	18	20	18
270	25	8	33	8	13	9
310	15	5	20	6	15	8
330	8	1	9	12	0	10
360	10	1	11	2	4	2

For those tubes meeting both the L criterion and the former ΔD criterion, circumferential growth is of no consequence since there are no outstanding issues relative to HEJ structural integrity. Reference 7 of WCAP-15050 describes the acceptability of tubes meeting the ΔD criterion relative to the structural margins recommended by RG 1.121. Therefore, for projecting future circumferential growth relative to the L criterion, these tubes are excluded from further consideration.

The calculated mean arc length increase per EFPY can be applied to the PTIs currently in service (excluding those PTIs meeting the ΔD criterion) in order to postulate future populations of PTIs affected by the L criterion, as discussed below.

Postulated EOC 23 PTI Distribution

EOC 23 corresponds to the April 2000 RFO. The EOC 23 population of PTIs consists of two subgroups: 1) PTIs left in service which met the L criterion during the 1998 RFO, and 2) new indications first detected during the 2000 RFO. For those PTIs left in service following the 1998 RFO, i.e., at the beginning of cycle (BOC) 23, the mean arc length increase reported in Table 1, at the corresponding initial arc length bin, is added to the BOC 23 arc length in order to project an EOC 23 arc length. The arc length increase reported in Table 1 is adjusted for the expected cycle 23 EFPY. The distribution of new indications expected at EOC 23 is assumed to be identical to the distribution of new indications reported during the 1998 RFO (i.e., at EOC 22). Figure 4 shows the postulated EOC 23 distribution of PTIs for SG A, and Figure 5 shows the postulated EOC 23 distribution of PTIs for SG B.

Postulated EOC 24 PTI Distribution

EOC 24 corresponds to the September 2001 RFO, in which SG replacement is planned. The EOC 24 population of PTIs consists of two subgroups: 1) PTIs left in service which met the L criterion during the 2000 RFO, and 2) new indications previously undetected during the 2000 RFO. For those PTIs left in service following the 2000 RFO, i.e., at the beginning of cycle (BOC) 24, the mean arc length increase reported in Table 1, at the corresponding initial arc length bin, is added to the BOC 24 arc length in order to project an EOC 24 arc length. The arc length increase reported in Table 1 is adjusted for the expected cycle 24 EFPY. The distribution of new indications expected at EOC 24 is assumed to be identical to the distribution of new indications reported during the 1998 RFO (i.e., at EOC 22). Figure 6 shows the postulated EOC 24 distribution of PTIs for SG A, and Figure 7 shows the postulated EOC 24 distribution of PTIs for SG B.

NRC Question 3

Given the PTI growth rate, demonstrate that all tubes having circumferential PTIs satisfy the safety margins in Regulatory Guide at the end of cycle 24. If tubes with circumferential PTIs do not satisfy the safety margins in Regulatory Guide 1.121, provide a criterion (limit) for the growth of the circumferential PTIs such that the degraded tubes at the end of cycle 24 will satisfy the safety margins in Regulatory Guide 1.121. Tubes having circumferential PTIs that do not satisfy the growth criterion (limit) would need to be plugged.

WPSC Response to Question 3

Table 4 of WCAP-15050 provides the summary of failure pressure test results for the specimens used in the qualification testing of HEJ joint strength. As reported in WCAP-15050, the probability of failure of the HEJ joint test configuration, at a differential pressure of less than or equal to 3 times the design differential pressure (3ΔP) of 4800 psi, is approximately 5%. This is for an HEJ joint with a 360 degree, 100% throughwall PTI located 0.95 inches from the hardroll upper transition (HRUT).

Under these conditions, there is no interference lip or ligamentation providing additional strength. It is expected that any PTI in service at EOC 24 with either 1) the presence of an interference lip, or 2) less than a 360 degree, 100% throughwall crack (i.e., ligamentation), has adequate strength such that the probability of HEJ joint failure at 3ΔP will be extremely low. A combination of both ligamentation and an interference lip would enhance the joint strength even further. Each of these aspects is discussed below.

Interference Lip

As demonstrated in WCAP-15050, an interference lip is not necessary for a degraded HEJ joint to meet RG 1.121 structural margins. However, if an interference lip is present, it provides additional strength to the degraded joint. Testing performed in 1995 (as reported in reference 4 of WCAP-15050) demonstrates the additional strength an interference lip provides. An indication 1.1 inches below the bottom of the HRUT would be expected to contain a lip of material formed by the transition. This assumes a hardroll length of approximately 1.0 inch as described in WCAP-15050. This lip must be drawn over the sleeve hardroll length in order for disassociation of the sleeve from the parent tube to occur. For specimens where the tube was completely machined at the elevation corresponding to 1.1 inches below the bottom of the HRUT, structural capacity of the joints was found to be nearly two times the most limiting RG 1.121 3ΔP end cap load for KNPP.

The distance from the bottom of the HRUT to the PTI was measured for each PTI reported during the 1998 RFO. The results are shown in Figure 8. The mean distance from the bottom of the HRUT to the PTI was 1.25 inches for both SGs, with a standard deviation of 0.12 inches. Based on the location of the PTI relative to the HRUT, 93% of the PTIs, on average, would be expected to be greater than or equal to 1.1 inches below the bottom of the HRUT.

Ligamentation

WCAP-15050 demonstrates that RG 1.121 margins are met for 360 degree, 100% throughwall cracks, with no credit taken for additional margin provided for by ligamentation or segmentation of the crack features. Ligamentation can provide a great deal of additional strength. Testing performed in 1994 (as reported in reference 3 of WCAP-15050) demonstrates the additional strength provided by ligamentation. Tubes were slit 100% throughwall from 120 degrees to 240 degrees and were positioned such that the slits were located at the top of the hardroll lower transition. Test results and observations indicated that upon loading, the bending moment applied through the nondegraded ligament caused a deflection of the tube and sleeve in the direction of the slit. This produced a sufficiently large bending lockup that in most cases, even with a 240 degree throughwall slit, the sleeve failed in tension at approximately 8,000 pound load. For those specimens that failed in the ligament, the ligament failure loads were approximately twice the tensile overload capacity of the tube. This considered only the nondegraded ligament area loaded in tension and was considerably greater than the most limiting RG 1.121 loading.

From the postulated EOC 24 distribution of PTIs, 80% of the tubes in SGA and 83% of the tubes in SGB would contain indications whose arc length would be less than 240 degrees. Again, remember the arc length measurements performed by Zetec encompassed the entire range of degradation, which assumes no ligamentation. The measurements also assumed that degradation was 100% throughwall throughout the entire reported extent. This is an extremely conservative assumption in light of tube pull results showing considerable ligamentation over the entire tube circumference.

For the two tubes destructively examined in 1995, field arc length measurements indicated 300 to 360 degree degradation while parent tube ligament failure loads exceeded 10,000 lbs. The end cap load corresponding to 3ΔP for the Kewaunee SGs is approximately 2450 lbf. Frictional loads after ligament separation exceeded the most limiting RG 1.121 loading. Each tube contained approximately twenty ligaments around the tube circumference. For one tube, the crack location was at the top of the hardroll lower transition

Based on the postulated EOC 24 population of inservice PTIs, 81.5% of the PTIs, on average, would be expected to have arc lengths less than 240 degrees, and 18.5% would have arc lengths in excess of 240 degrees.

Conclusions

Table 4 of WCAP-15050 provides the summary of failure pressure test results for the specimens used in the qualification testing of HEJ joint strength. As reported in WCAP-15050, the probability of failure of the HEJ joint test configuration, at a differential pressure of less than 3ΔP is approximately 5%. This is for an HEJ joint with a 360 degree, 100% throughwall PTI located 0.95 inches from the HRUT, i.e., with no consideration of an interference lip or ligamentation providing additional strength. As discussed above, PTIs found in the Kewaunee SGs are different than the HEJ test configuration, i.e., a large majority of the PTIs contain both an interference lip and/or ligamentation, which provides additional strength relative to the test configuration.

Based on the location of the PTI relative to the HRUT, 93% of the PTIs, on average, would be expected to be greater than or equal to 1.1 inches below the bottom of the HRUT. Assuming that a PTI less than 1.1 inches below the bottom of the HRUT would not exhibit enough of an interference lip to provide additional strength, it follows that the combined probability of a PTI in service at the end of cycle 24 which may exhibit failure pressures less than 3ΔP is on the order of 3.5×10^{-3} (0.05 x 0.07).

Based on the postulated EOC 24 population of inservice PTIs, 18.5% of the PTIs, on average, would be expected to have arc lengths in excess of 240 degrees. Assuming that an arc length in excess of 240 degrees would not exhibit enough ligamentation to provide additional strength (considering the 1994 testing as an indication of ligament strength), it follows that the combined probability of a PTI in service at the end of cycle 24 which may exhibit failure pressures less than 3ΔP is on the order of 9.3×10^{-3} (0.05 x 0.185).

Taking into account the influence of both ligamentation and an interference lip in providing additional strength relative to the test configuration, the combined probability of any PTI not meeting RG 1.121 structural margins at the end of cycle 24 is on the order of 6.5×10^{-4} (0.05 x 0.185 x 0.07). Therefore, it can be concluded that all PTIs left in service at the end of cycle 24 will meet RG 1.121 guidelines with regard to structural integrity. This is without consideration of tube restraint provided by the tube support plates.

Figure 1

Steam Generator A
Distribution of Parent Tube Indications From the 1998 Refueling Outage

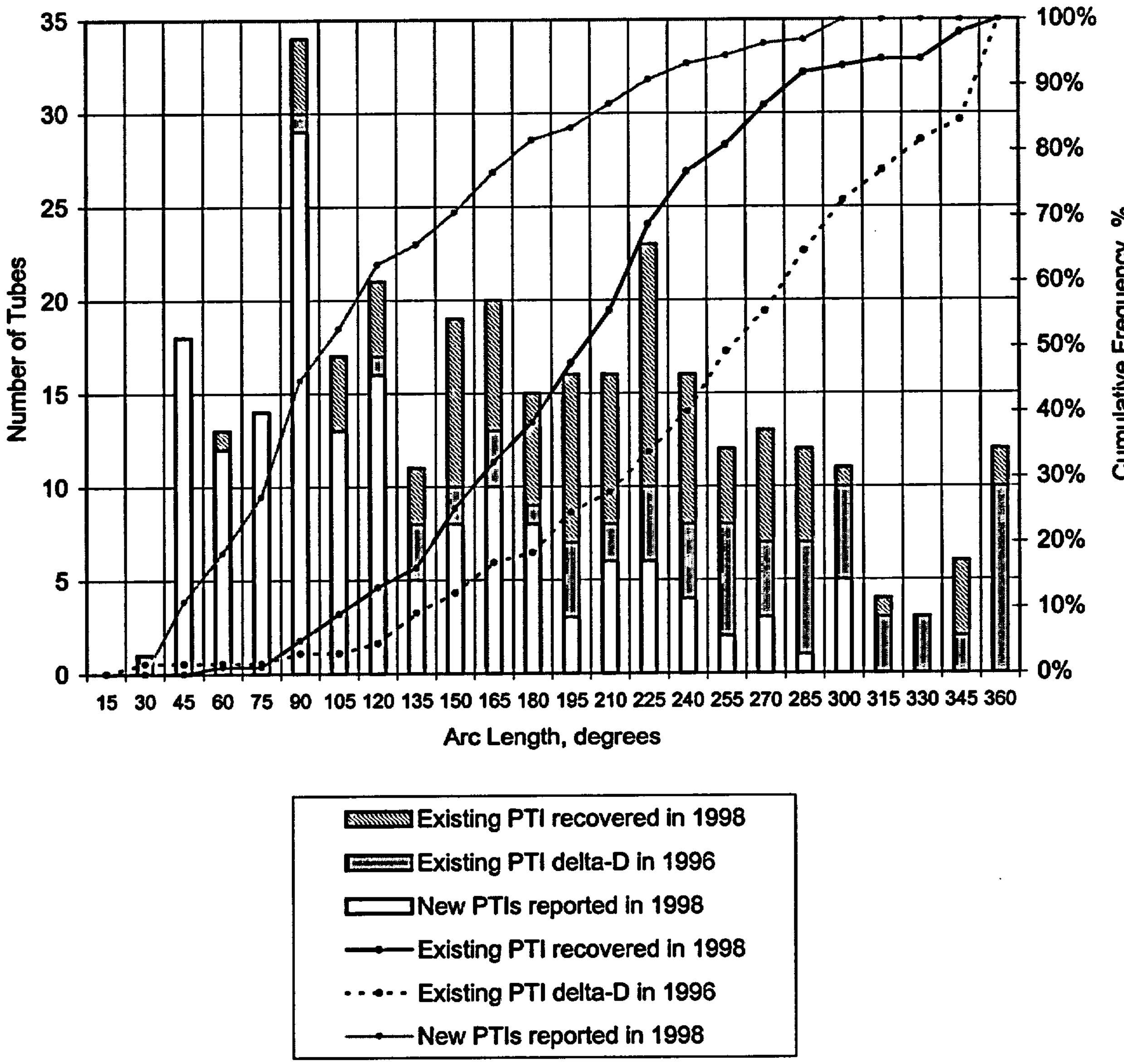

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Figure 2

Steam Generator B
Distribution of Parent Tube Indications From the 1998 Refueling Outage

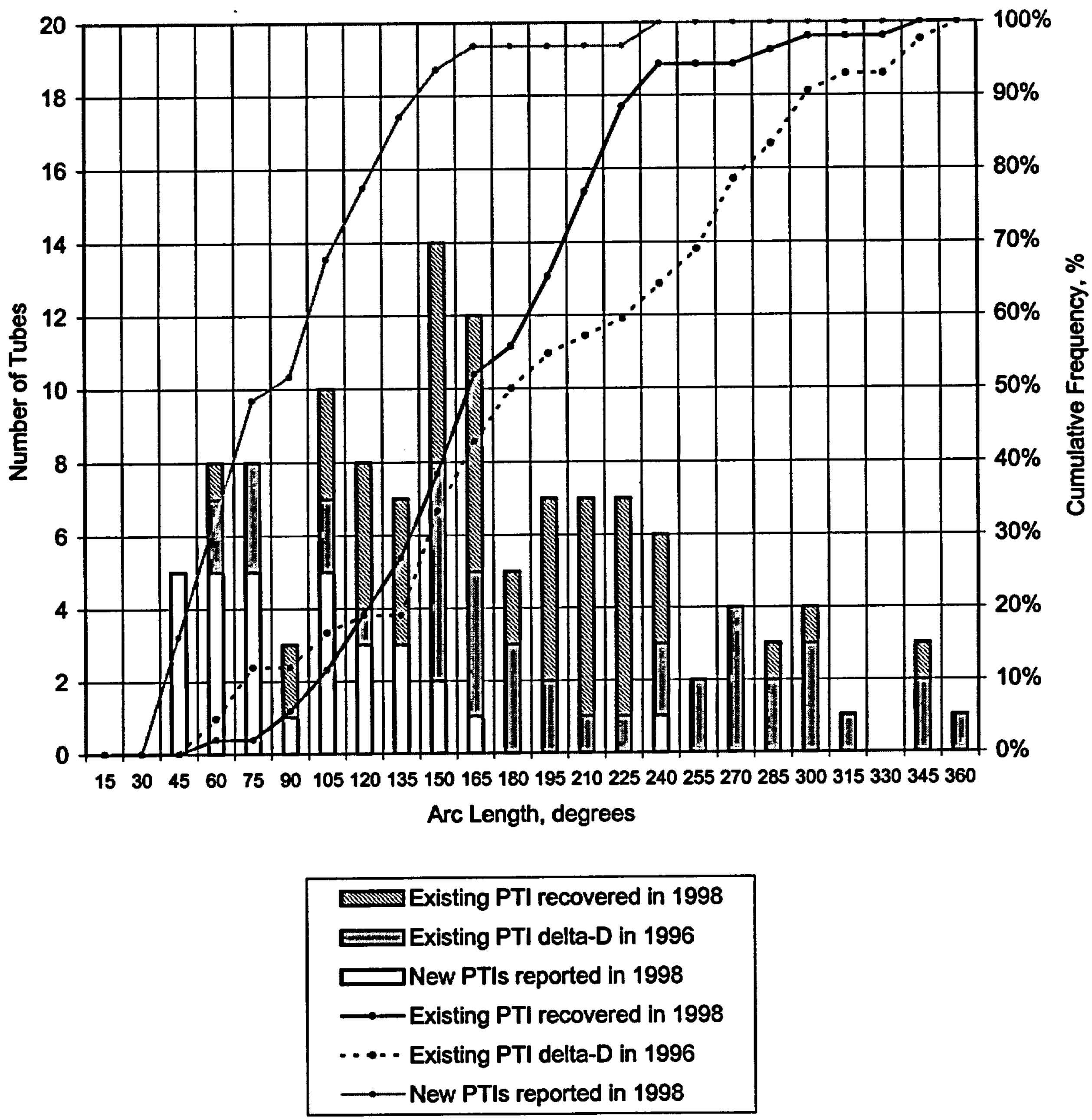

Figure 3

Arc Length Change per EFPY

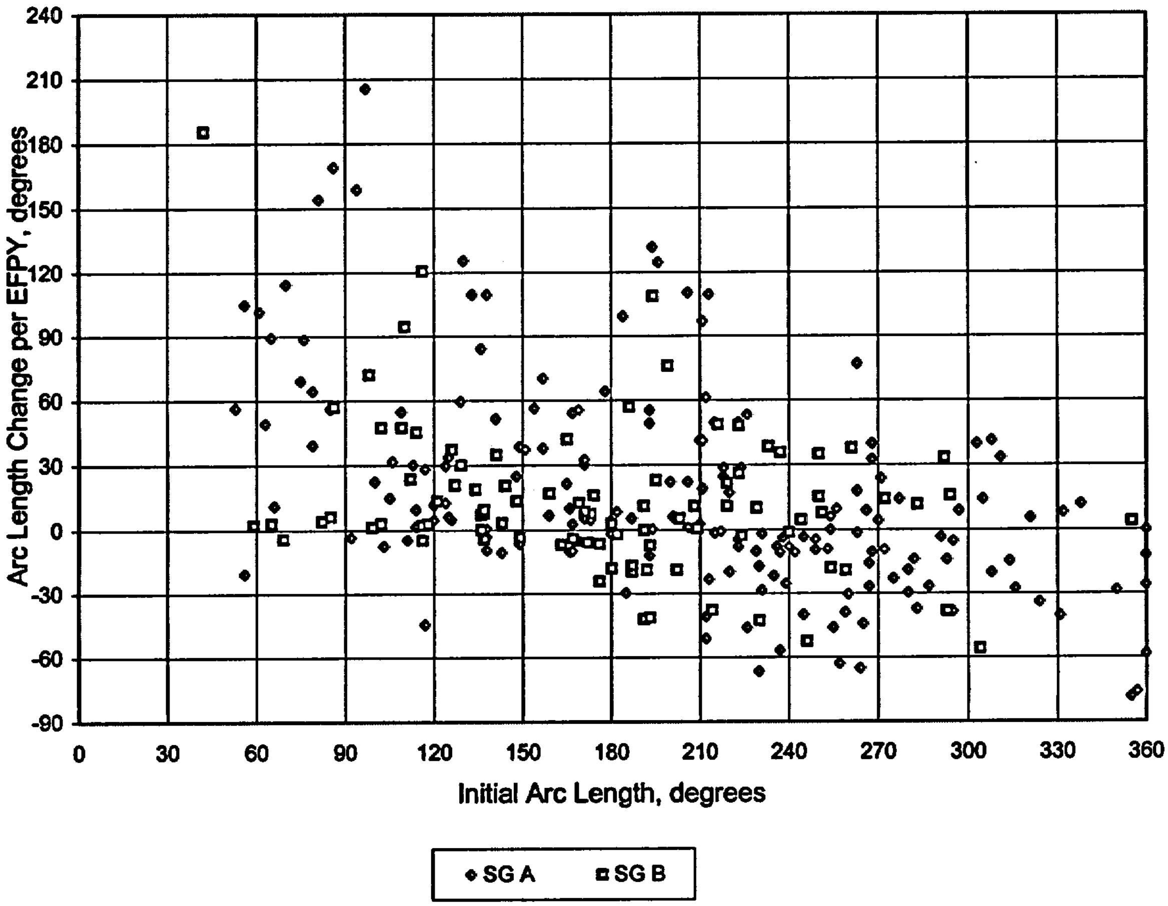

Figure 4

Steam Generator A
EOC 23 Distribution of PTIs

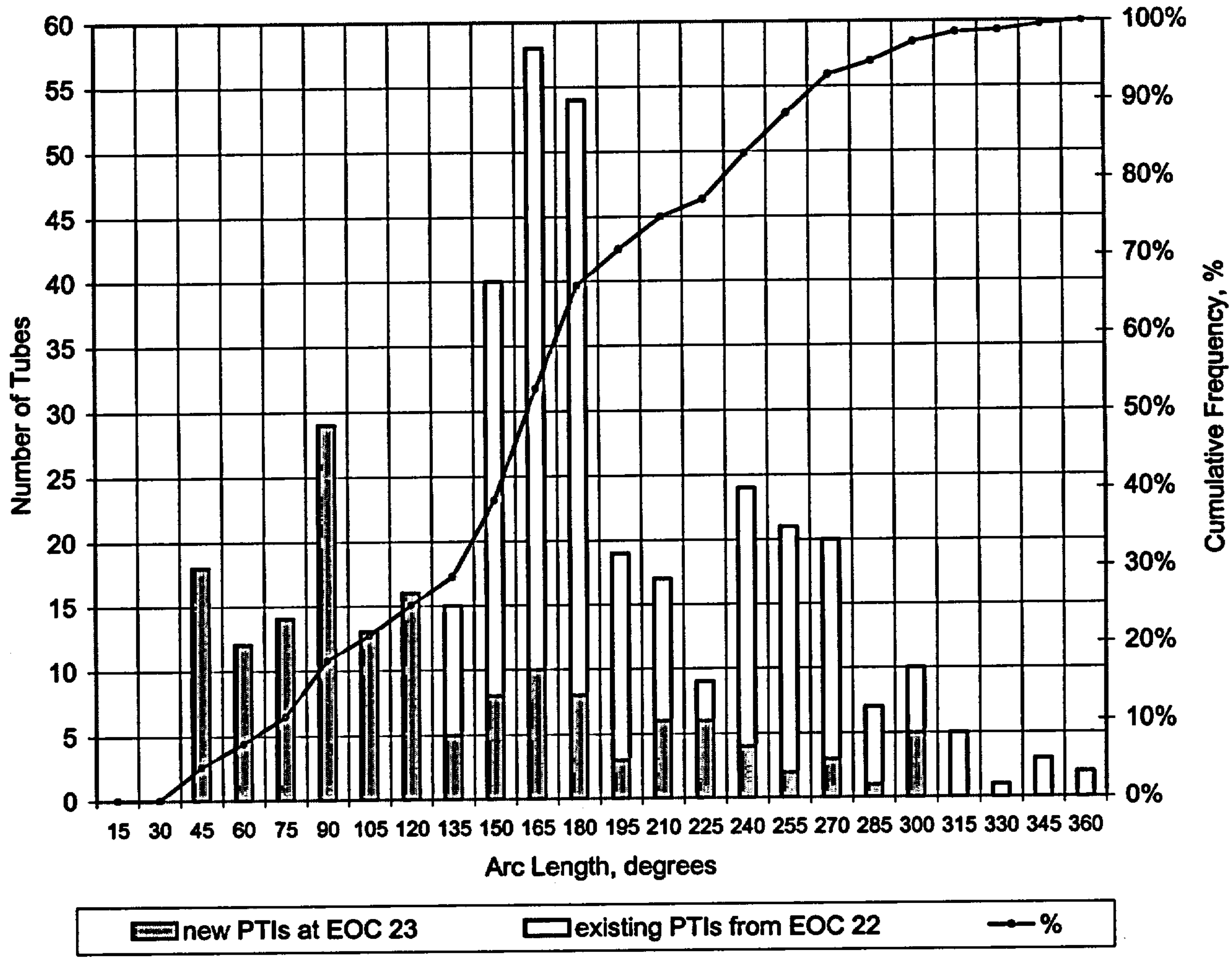

Figure 5

Steam Generator B
EOC 23 Distribution of PTIs

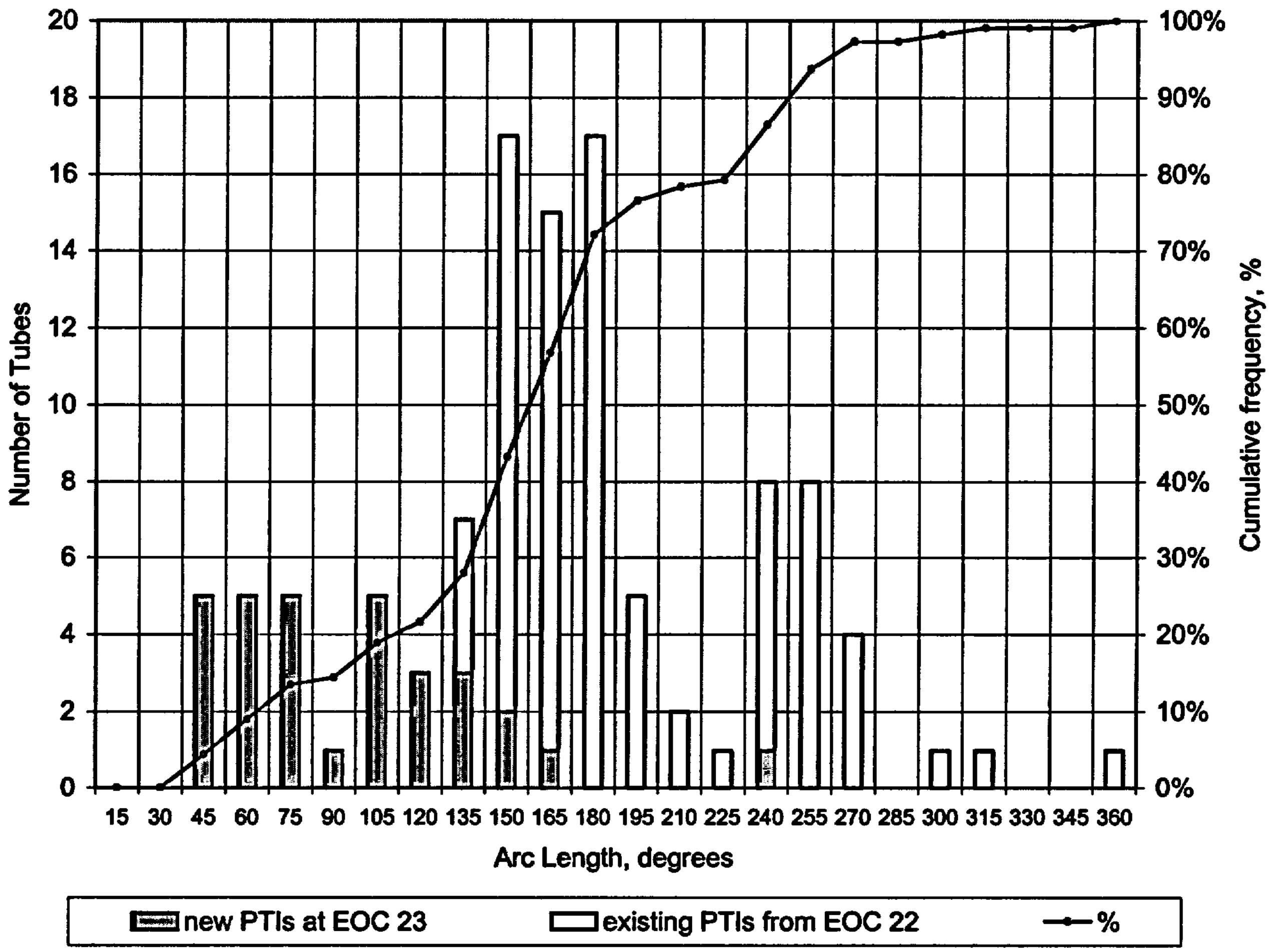

Figure 6

Steam Generator A
EOC 24 Distribution of PTIs

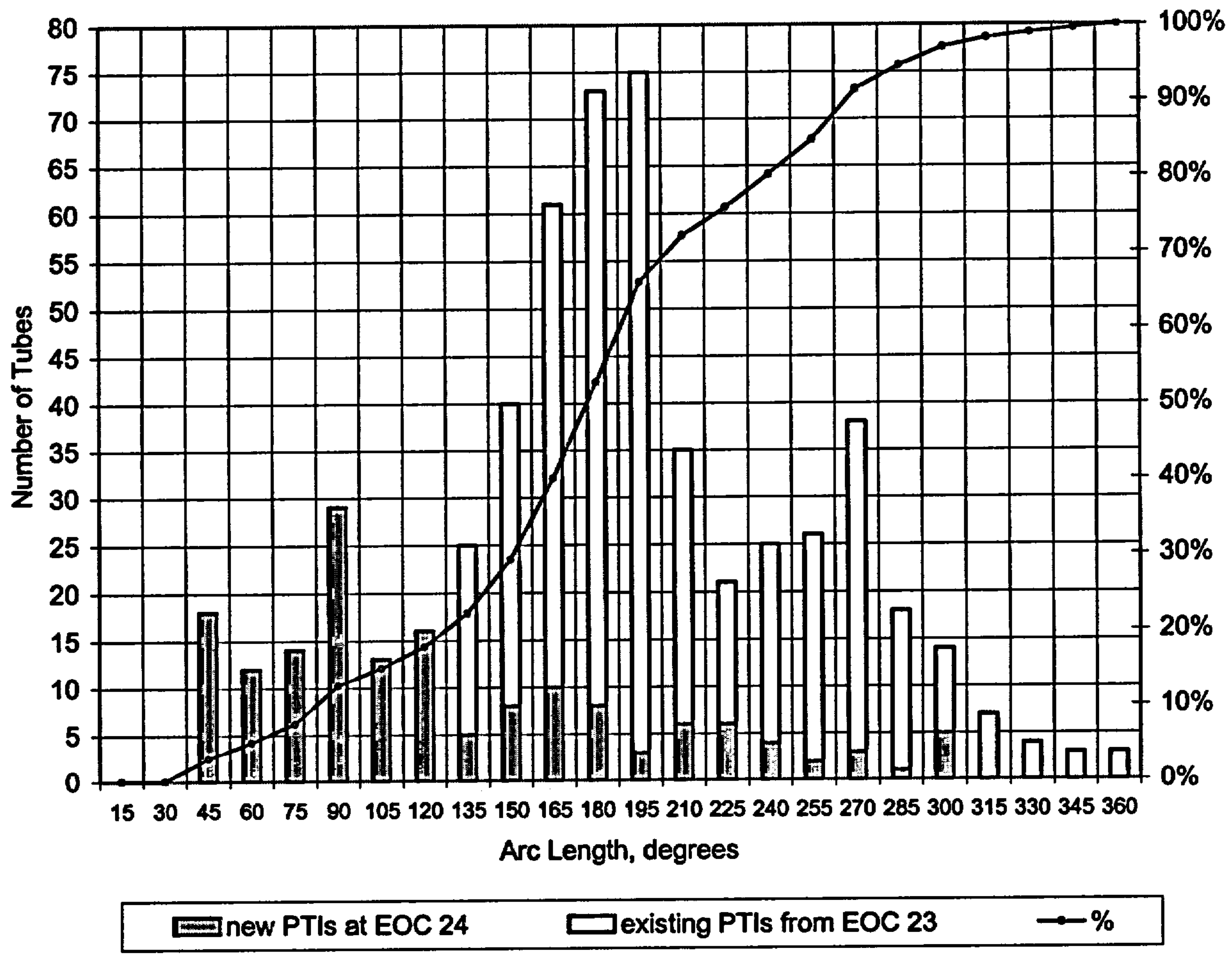

Figure 7

Steam Generator B
EOC 24 Distribution of PTIs

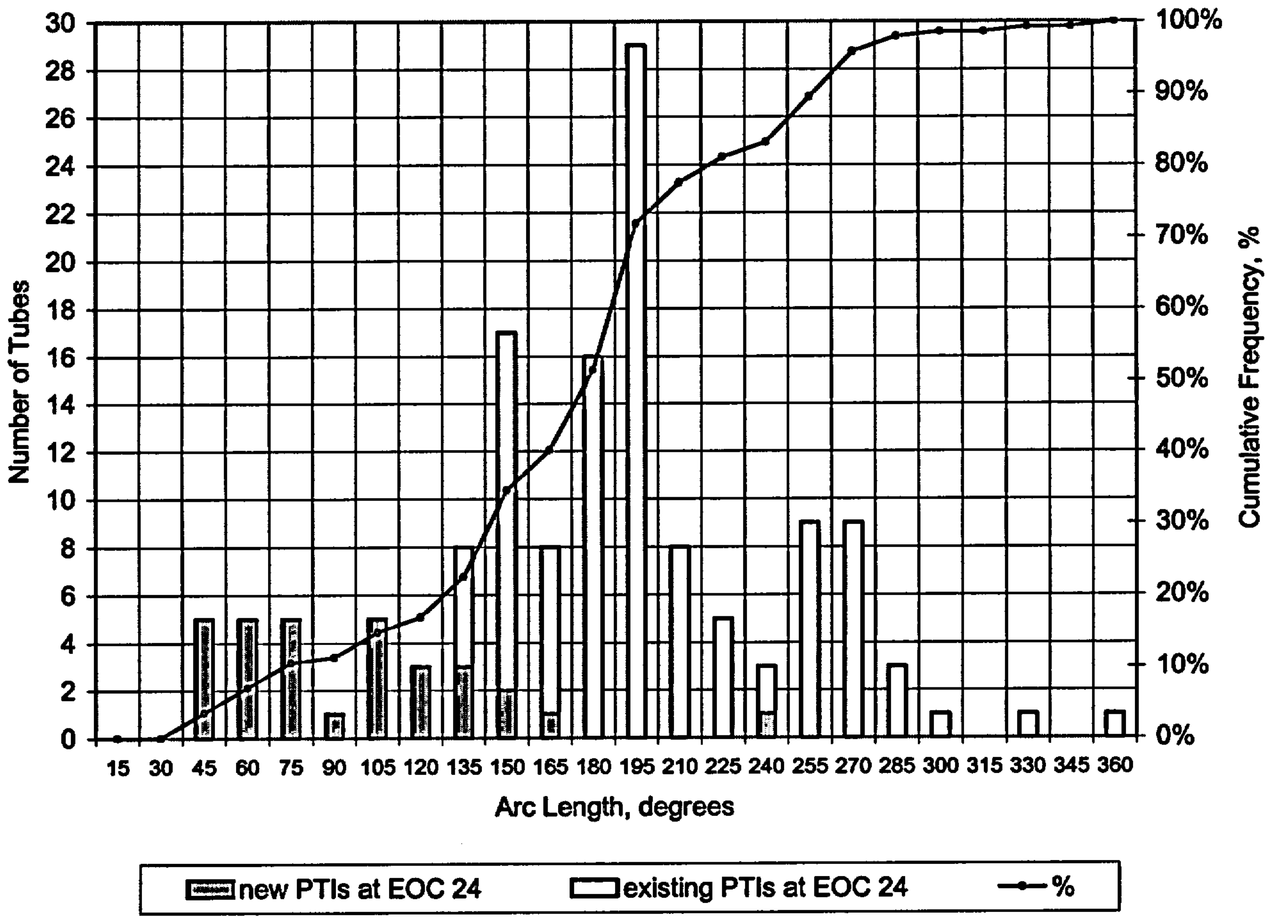

Figure 8

PTI Indication vs. Distance Below Bottom of HRUT