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Downers Grove, IL 60515-5701

September 10, 1996

ComEd

Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attn: Document Control Desk

Subject: Braidwood Station Unit 1
NRC Docket Number: 50-456

Additional Information Pertaining to Operating Interval Between Eddy Current Inspections for Circumferential Indications in the Braidwood Unit 1 Steam Generators

References:

1. H. Stanley letter to the Nuclear Regulatory Commission dated August 2, 1996, transmitting Operating Interval Between Eddy Current Inspections for Circumferential Indications in the Braidwood Unit 1, Steam Generator Tubes

2. H. Stanley letter to the Nuclear Regulatory Commission dated August 20, 1996, transmitting Operating Interval Between Eddy Current Inspections for Circumferential Indications in the Braidwood Unit 1, Steam Generator Tubes

3. D. Lynch letter to I. Johnson letter transmitting Requests for Additional Information dated September 9, 1996, Pertaining to Operating Interval Between Eddy Current Inspections for Circumferential Indications in the Braidwood Unit 1 Steam Generators

In the Reference 1, the Commonwealth Edison Company (ComEd) provided the Nuclear Regulatory Commission (NRC) with the "Braidwood Unit 1 Cycle Length Assessment Report Addendum" which justified operation of the Braidwood Unit 1 for a full cycle prior to steam generator tube inspection. Reference 2 transmitted a supplement to the report which contained the Conditional Burst Probability explanation. On August 15th and 26th, ComEd met with the NRC to discuss Braidwood's submittal. During these meeting, additional issues arose.

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Attachment A contains additional information of the Braidwood Unit 1 full cycle assessment, that was in response to NRC questions at the August 15th meeting. The issues addressed are:

(1) Increase the number of circumferential indications used in the Braidwood Unit 1 full cycle analysis to reflect the results of the number of indications detected at Byron Unit 1 in 1995 and 1996, and

(2) Regarding the voltage integral software, assess the potential for the largest average voltage and largest maximum voltage to occur on different scan lines.

Additionally, during the August 26th meeting, an issue was raised regarding the distribution of indications assumed in the Braidwood Unit 1 end-of-cycle (EOC) calculation Look-back approach.

Additionally, Reference 3 transmitted the NRC Request for Additional Information on the elimination of the Braidwood Cycle Length. ComEd has completed the response to some of these questions, which are provided in Attachment B. Subsequent submittals will be forwarded to the Staff as the responses to the questions are finalized.

If you have any questions concerning this correspondence please contact Denise Saccomando, Senior PWR Licensing Administrator at (630) 663-7283.

Sincerely,

Harold Gene Stanley
Site Vice President
Braidwood Station

Attachments

cc:

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Office of Nuclear Safety-IDNS

ATTACHMENT A

Braidwood Unit 1 Cycle Length Assessment

Report Addendum

September 10, 1996

Executive Summary:

On August 26, 1996, ComEd presented to the NRC Staff additional information on the Braidwood Unit 1 full cycle assessment. The issues discussed are:

(1) Increase the number of circumferential indications used in the Braidwood Unit 1 full cycle analysis to reflect the results of the number of indications detected at Byron Unit 1 in 1995 and 1996, and

(2) Regarding the voltage integral software, assess the potential for the largest average voltage and largest maximum voltage to occur on different scan lines.

Additionally, during the August 26th meeting, an issue was raised regarding the distribution of indications assumed in the Braidwood Unit 1 end-of-cycle (EOC) calculation Look-back approach.

ComEd has concluded:

- A conservative BOC-6 distribution for Braidwood Unit 1 was determined and grown 461 days to determine an EOC-6 distribution. When compared to the burst and leak limits, the steam generator tube integrity requirements are satisfied.

- A comparison of the look-back approach results to the POD approach results provided in ComEd's August 2nd and August 20th submittals, shows that the two approaches have similar results for burst, the look-back approach has an increase in predicted Braidwood Unit 1 EOC-6 leak rate.

- The Integral Voltage sensitivity study to scan line selection determined that over 92% of the time, the largest average voltage occurs in the scan line with the largest maximum voltage, and the variability of the average voltage due to the selection of the scan line with the maximum voltage is significantly less than the analyst variability input into the EOC analysis. Therefore, the use of the 20% is conservative. Additionally, the completed sensitivity study demonstrates that the contribution of uncertainty due to circumferential scan line selection, based upon largest maximum voltage, is not significant.

- With the operation of Braidwood Unit 1 to March, 1997, all tube integrity requirements are met using 2 different approaches for Braidwood Unit 1 EOC-6 indication distributions.

1.0 Introduction:

On August 26, 1996 ComEd presented additional information to the NRC on the Braidwood Unit 1 full cycle assessment. The additional information was in response to NRC questions at a meeting on August 15, 1996. The issues were understood to be:

(1) ... number of circumferential indications used in the Braidwood Unit 1 full cycle analysis does not address the results of the number of indications detected at Byron Unit 1 in 1995 and 1996 (Look-Back Approach, Section 2.0), and

(2) Using the voltage integral software, there is a potential for the largest average voltage and largest maximum voltage to occur on different scan lines (Integral Voltage Sensitivity, Section 3.0).

This report documents the response to these issues. In addition to the two issues from the August 15, 1996, meeting this report documents, in Section 4.0, the response to a question identified in the August 26, 1996, meeting regarding the distribution of indications assumed in the Braidwood Unit 1 end-of-cycle (EOC) calculation Look-back approach.

This response identifies an additional distribution of indications referred to as the EOC approach. This approach assumes the EOC at Braidwood Unit 1 will be similar to Byron Unit 1 EOC-6 and includes all the Byron Unit 1 1994 indications repaired or detected through look-back of 1995 and 1996 indications. This approach is considered to be the best means to characterize the EOC distribution at Braidwood Unit 1 because of the comprehensive re-evaluation of the Byron 1994 indications, is a direct measure of the variable of interest (i.e. EOC distribution), and minimizes uncertainty associated with growth rates. The key element in this approach is to recognize that in March, 1997 Braidwood Unit 1 will have less operating time than Byron Unit 1 had in 1994.

Subsequent to the August 26, 1996, meeting a request for additional information (RAI) has been received regarding the deletion of the Braidwood Unit 1 Mid-Cycle Inspection (Reference 4). The response to RAI questions is included in this report as Attachment B. A summary of the RAI questions for which a response is included in this report is provided below.

(1) Leak rate analysis in previous submittals used deterministic techniques and a leakage threshold to determine Braidwood Unit 1 EOC leakage. The RAI response presents a new analysis method using a log-logistic probability of leak function to calculate the EOC leakage based upon EOC voltage distributions.

This method will adequately account for uncertainties in the leakage data. Results of application of this method will be provided upon resolution of NRC questions on input parameters of the EOC analysis. (RAI-16)

(2) The August 2, 1996, submittal leak rate analysis used the maximum voltage for leakage determination. This report includes the leak rate relationship for average voltage from industry tube pull and insitu leak testing leak rate data. A log-logistic probability of leak function vs. average voltage is also provided. Future analysis of circumferential indication distribution leak rate will continue to use maximum voltage, since it is the voltage parameter which provides the best indication of the depth of degradation. (RAI-14)

(3) Braidwood Unit 1 growth data has not been submitted previously to NRC due to difficulties with converting February 1995 inspection ECT data to EddyNet95. The conversion has been completed and the look-back of October 1995 indications to February 1995 is complete, the results are included in this submittal. In lieu of application of growth rates the Byron Unit 1 EOC-6 distribution will be used as the Braidwood Unit 1 EOC-6 distribution (adjusted for NDE uncertainty). (RAI-2)

(4) The industry burst limits from Reference 1 Section 5.4 were based upon Braidwood Unit 1 LTL values and not industry LTL values. Voltage limits (average and maximum) for burst have been defined using industry LTL values. These limits do not significantly change from what is reported in Reference 1. For site specific application of the burst limits, the Braidwood Unit 1 LTL properties will continue to be used. (RAI-10)

(5) A clarification of the scope of Byron 1996 voltage integral software look-back is provided. (RAI-4)

2.0 Braidwood Unit 1 End of Cycle 6 Burst and Leak Results (Look-Back Approach):

This section provides the supporting information discussed in the meeting held on August 26, 1996.

In order to provide a Braidwood Unit 1 BOC distribution which closely approximates the result of inspections at Byron Unit 1 in 1995 and 1996, an additional BOC distribution was used for calculation of the Braidwood Unit 1 EOC-6 distribution. This BOC-6 distribution includes the detected and repaired indications at Braidwood in 10/95 and 1994 Byron indications detected during look-back of 1995 and 1996 indications. This BOC-6 distribution is grown to EOC-6 similar to that for the POD approach described in Reference 1. Based upon the EOC-6 distribution, burst and leak results can be assessed against limits established in Reference 1 Section 5.4 and 7.0. This approach is very

conservative because it grows the EOC-6 distribution at Byron an additional cycle beyond EOC-6 at Braidwood. This section describes the basis of the distribution and the results.

2.1 Braidwood Unit 1 Beginning of Cycle 6 (Look-Back Approach):

The Byron Unit 1 EOC-6 inspection in 1994 is used as the basis for the Braidwood Unit 1 BOC-6 distribution in this analysis. The indications (1082 total) in the look-back approach include:

1. Indications detected and repaired at the last Braidwood Unit 1 inspection (EOC-5, October 1995) for all SG's.
2. Indications (0.080" RPC) detected and repaired in 1995 (SG B) and 1996 (SG C) and present in look-back to 1994,
3. Because +point was not used in 1994 the number of indications is increased by the 0.080" RPC confirmation rate of +point for the particular inspection year they were detected (i.e. 0.76 for 1995, 0.343 for 1996),
4. The 1996 look-back was in SG C which had larger but not more indications than SG D. The 1996 look-back to 1994 results are increased by the ratio of SG D indications to SG C indications (i.e. 1.137)

Table 1 presents a summary of these results.

Braidwood Unit 1 is presently in cycle 6 of operation. At the end of the upcoming cycle, EOC-6, Braidwood Unit 1 will have operated 6.78 EFPY. Byron Unit 1 EOC-6 inspection was performed in 1994 after 6.949 EPFY. In effective full power years Braidwood Unit 1 will have operated less than Byron Unit 1.

The inspection performed at Byron Unit 1 in 1994 was the first inspection which used techniques that are sensitive to circumferential cracks. The indications seen at Byron in 1994 are the largest top of the tube-sheet circumferential indications detected thus far at Byron or Braidwood Unit 1, and most likely were in service for more than one cycle of operation. From ECT inspection results (Reference 1 Figure 3.1 and 5.1) the 0.080" RPC has a high probability of detection for large indications. Therefore, it is justified to include the Braidwood Unit 1 EOC-5 repaired indications (23 in all SG's) in the distribution of indications, and not the Byron EOC-6 repaired indications (128 in all SG's).

Application of the look-back approach for the Braidwood Unit 1 BOC-6 distribution is conservative for the following reasons:

1. Byron EOC-6 distribution is grown an additional cycle, 1 cycle beyond Braidwood 1 EOC-6,

2. Braidwood 1 indications from all 4 SG's included,
3. Repaired indications included in distribution.

The look-back approach distribution accounts for the detected indications at Braidwood Unit 1 as well as the inspection transients seen at Byron Unit 1 in 1995 and 1996 due to the +point probes and analyst sensitivity (with aid of EddyNet95 software).

The look-back approach BOC-6 distribution for average and maximum voltage is shown in Figure 1 and Figure 2. Figure 1 and Figure 2 also show the BOC-6 distribution used in the POD approach included in the Reference 1 report. The tails of the distributions are similar in both approaches because the majority of indications present in 1994 from the look-back data have small voltages. From comparison of these distributions the results of the burst limits, which are primarily a function of the tail are expected to be similar. Table 3a (average volts) and 3b (maximum volts) presents the distribution of indications assumed in the beginning of cycle distribution for the POD approach submitted in the Reference 1 report, the Look-Back approach presented here and the EOC approach discussed in Section 4.0 of this report.

2.2 Growth of BOC-6 distribution to EOC-6:

The look-back approach described in this section uses similar methods to grow the BOC-6 distribution to the end of cycle as described in Reference 1 Section 5.3. The BOC-6 distribution is grown 461 days using voltage growth rates and NDE uncertainty (probe wear and analyst uncertainty) from Reference 1 Section A.2. Growth rate data from Byron Unit 1 is used. The distribution of growth rates is shown in Figure 4.3 and 4.4 of Reference 1 for average and maximum volts, respectively.

The resulting look-back approach EOC-6 distribution is shown in Figures 3 and 4 for average and maximum voltage respectively. These figures show the distribution of the Braidwood Unit 1 10/95 repaired indications, the BOC-6 look-back approach distribution, and the EOC-6 distribution. The plots show the voltage vs the number of tubes at each of the corresponding voltages. Table 4a (average volts) and 4b (maximum volts) provides the Braidwood Unit 1 EOC-6 number of tubes vs. voltage bin for the POD approach provided in Reference 1, and the Look-back approach presented here. The results show that burst limits are satisfied as discussed below.

2.3 Assessment Against Burst Limits:

From Reference 1 Figure 5.5 and 5.6 voltage burst limits are defined from industry burst data. The limits at 3xNOdP (4035 psi) are 0.91 volts for average voltage and 3.64 volts for maximum voltage. The burst data is corrected for Braidwood Unit 1 LTL properties and the voltages are normalized to the same procedure as described in Reference 1 Section 6.2. The industry ECT data for the burst points was acquired using the 0.080" RPC;

therefore, the only correction factor applied to normalize the data to Byron and Braidwood data is the voltage normalization correction factor. Some insitu pressure test data was acquired with the 0.115" RPC and therefore an additional correction factor was applied to this data.

The two points which define the burst curve are Byron Unit 1 tube pulls which separated during the tube removal process. EDM simulations of the tubes degradation were simulated and burst tested. The EDM simulations do not account for all the small ligaments present and therefore add conservatism to the burst curve.

Based upon the burst limits described above the following results were obtained for the look-back approach:

| | | Max. Volts | Avg. Volts |
|---|---|---|---|
| 1. | Frequency > S.L. | 9.3E-6 | 1.6E-3 |
| 2. | Last Whole Tube | 1.7 Volts | 0.85 Volts |

Based upon these results and the conditional burst probability submitted in Reference 2 of 1.3E-5, burst requirements described in Reference 1 and 2 are satisfied for the look-back approach.

2.4 Assessment Against Leak Limits:

In Reference 1, Figure 7.1 a threshold of leakage is developed from industry tube pull leak tests and insitu pressure test leakage. The leakage is corrected to Braidwood Unit 1 main steam line break conditions at 2560 psi. From the figure a leakage threshold of 1.1 volts is established and a maximum leak rate of 0.16 gpm defined. Because a correlation of the leak rate data to voltage does not exist, the maximum leakage is assigned to all the tubes exceeding the leakage threshold.

From Figure 4 the EOC-6 number of tubes with maximum voltages greater than 1.1 volts has been determined to be 45. Assigning the maximum leak rate to this number of tubes results in an estimated EOC-6 leak rate from circumferential indications of 7.2 gpm. Based upon this leak rate combined with the leakage estimated from TSP ODSCC of 6.99 gpm (Reference 3) and 0.3 gpm allowable leakage from the unfaulted SG's the site allowable leakage limit of 26.8 gpm is satisfied (14.5 gpm).

2.5 Look-Back Approach Conclusions:

A conservative BOC-6 distribution for Braidwood Unit 1 was determined and grown 461 days to determine an EOC-6 distribution. When compared to the burst and leak limits, the

steam generator tube integrity requirements are satisfied. A comparison of the look-back approach results to the POD approach results (Reference 1) is provided in Figure 5. The two approaches have similar results for burst with the look-back approach having an increase in predicted EOC-6 leak rate.

3.0 Integral Voltage Sensitivity to Scan Line:

This section documents the information presented in the August 26, 1996, meeting regarding circumferential scan line sensitivity to average voltage.

A sensitivity study was performed to address a question regarding the potential for the scan line selected by the ECT analyst with the largest maximum voltage to not have the largest average voltage of the scan lines defining the indication. The objective of the study was to evaluate the sensitivity of average voltage to scan line selection.

In order to assess this question for the population of tubes used to assess the Braidwood Unit 1 EOC-6 distribution the following tubes were included within the scope of the study:

1. 23 Braidwood Unit 1 10/95 indications
2. 100 Byron Unit 1 1996 randomly selected indications of varying size
3. 57 Industry Tube Pull and Insitu Pressure Test Indications

The procedure followed for the study was as follows:

- For each indication, select the scan line with the largest maximum voltage. Then record the maximum and average voltage of the remaining scan lines which define the indication
- compare the average voltages of the scan line selected by the analyst, with the largest maximum voltage, and the scan line with the largest average voltage.

The results of this study conclude that for 166 out of the 180 indications analyzed the scan line with the maximum voltage also has the largest average voltage. For the remaining 14 of 180 indications the largest average voltage difference between the scan line with the largest maximum voltage and the largest average voltage of all scan lines is 16.7%. The mean average voltage difference between the scan line with the largest maximum voltage and the scan line with the largest average voltage of the 14 of 180 indications is 10%.

Use of the voltage integral software for the Byron and Braidwood look-backs for calculation of the average voltage requires the analyst to select the scan line with the maximum voltage. This sensitivity study addresses the uncertainty of average voltage when selecting the appropriate scan line.

The uncertainty used in the Braidwood Unit 1 EOC distribution analysis uses is 20% (Reference 1 Section A.2.2). This uncertainty was developed from blind tests performed at Byron in 1996 without use of the voltage integral software. This blind test uncertainty includes the analyst uncertainty of selecting the appropriate scan line and of appropriately defining the area of the worst degradation.

3.1 Conclusions:

The conclusions of the Integral Voltage sensitivity study to scan line selection are as follows:

1. Over 92% of the time, the largest average voltage occurs in the scan line with the largest maximum voltage. This is the scan line from which the analysts were instructed to obtain the average voltage.

2. For the remaining 8% of the tubes the average voltage may differ by 10% on average or 16.7% maximum.

3. Based upon the frequency and magnitude of this uncertainty, the 20% analyst variability used in the Braidwood Unit 1 EOC-6 calculations bounds this result.

4.0 Braidwood Unit 1 End of Cycle 6 Distribution (EOC Approach):

This section provides information in response to questions raised at the August 26, 1996 NRC meeting regarding the consideration of TTS circumferential indications detected and repaired at the Byron Unit 1 1994 inspection (EOC-6).

In order to provide a Braidwood Unit 1 EOC distribution which closely approximates the result of inspections at Byron Unit 1 in 1995 and 1996 an additional EOC distribution will be used for calculation of the Braidwood Unit 1 EOC-6 distribution, this distribution is called the EOC approach. This Braidwood Unit 1 EOC-6 distribution uses the Byron EOC-6 distribution including all repaired tubes and tubes identified with circumferential indications from look-backs. The distribution is adjusted for NDE uncertainty but is not grown because the distribution represents where Braidwood Unit 1 will be if it were to operate a full cycle to March of 1997. Based upon the Braidwood Unit 1 EOC-6 distribution, burst and leak results can be directly assessed against limits established in Reference 1 Section 5.4 and 7.0. This section describes the basis of the distribution. Results of the Braidwood Unit 1 EOC-6 distribution from this approach may be affected by analysis currently being performed to address NRC RAI questions, and therefore is not presented at this time.

4.1 Braidwood Unit 1 Beginning of Cycle 6 (EOC Approach):

An additional Braidwood EOC-6 analysis has been performed using the entire population of Byron Unit 1 EOC-6 indications in the worse steam generator (SG) from look-back data and the entire population of Byron Unit 1 1994 repaired indications. Because the 1994 inspection at Byron Unit 1 was after 6.949 EFPY and the Braidwood Unit 1 inspection in March of 1997 (EOC-6) will be after approximately 6.78 EFPY, this distribution is conservative. This distribution is called the EOC approach and includes 1186 indications.

The basis of the indications is discussed below and is presented in Table 2.

1. Indications (0.080" RPC) detected and repaired in 1995 (SG B) and 1996 (SG C) and present in look-back to 1994,
2. Because +point was not used in 1994 the number of indications is increased by the 0.080" RPC confirmation rate of +point for the particular inspection year they were detected (i.e. 0.76 for 1995, 0.343 for 1996),
3. The 1996 look-back was in SG C which had larger but not more indications than SG D. The 1996 look-back to 1994 results are increased by the ratio of SG D indications to SG C indications (i.e. 1.137)
4. Indications detected and repaired at Byron Unit 1 EOC-6 inspection (1994) for all SG's.

Table 2 presents a summary of these results. Table 3a (average volts) and 3b (maximum volts) identifies the BOC distribution with the number of indications for each 0.1 volt voltage bin. Indications are placed in the top of the range of the voltage bins (e.g. 0.44 volts placed in the 0.45 volt average and 0.50 volt maximum voltage bins).

4.2 Growth of BOC-6 distribution to EOC-6:

The EOC approach described in this section uses similar methods to adjust the BOC-6 distribution for NDE uncertainty as described in Reference 1 Section 5.3. Because the 1994 inspection at Byron Unit 1 was after 6.949 EFPY and the Braidwood Unit 1 inspection in March of 1997 (EOC-6) will be after approximately 6.78 EFPY, this distribution is conservative and is not grown.

The resulting Braidwood Unit 1 BOC-6 distribution for the EOC approach before adjustment for NDE uncertainty is presented in Figures 6 & 7.

Results of the Braidwood Unit 1 EOC-6 distribution from this approach may be affected by analysis in response to the NRC RAI, and therefore, is not presented at this time.

5.0 Conclusions:

1. Additional conservative Braidwood Unit 1 EOC-6 distributions have been assessed to demonstrate compliance to steam generator tube integrity requirements. The EOC approach will be used for future assessment of burst and leak.

2. A sensitivity study has been completed which demonstrates that the contribution of uncertainty due to circumferential scan line selection, based upon largest maximum voltage, is not significant.

6.0 References:


1. Letter to US NRC, Operating Interval Between Eddy Current Inspections for Circumferential Indications in the Braidwood Unit 1 Steam Generators, Dated August 2, 1996

2. Letter to US NRC, Operating Interval Between Eddy Current Inspections for Circumferential Indications in the Braidwood Unit 1 Steam Generators, Dated August 20, 1996

3. Braidwood Unit 1 Cycle 6 Interim Plugging Criteria 90 Day Report January 1996

4. NRC Request for Additional Information Regarding the Proposed Deletion of the Braidwood, Unit 1 Mid-Cycle Steam Generator Tube Inspection, September 9, 1996

## Table 1

### Braidwood Unit 1 Beginning of Cycle Distribution
### Look-Back Approach Summary

| Basis | Number of Indications | Plus Point Correction | Worse SG Correction | Total |
|---|---|---|---|---|
| Braidwood EOC-5 | 23 | none | All SG's incl. | 23 |
| Byron 1995 Look-back to 1994 | 618 | 1.31 | Worse SG Analyzed | 809 |
| Byron 1996 Look-back to 1994 | 78 | 2.91 | 1.137 | 258 |
| Total | | | | 1090 |

Note: 1082 indications were used in the EOC analysis the difference in tubes is due to ECT data not copying

## Table 2

### Braidwood Unit 1 Beginning of Cycle Distribution
### EOC Approach Summary

| Basis | Number of Indications | Plus Point Correction | Worse SG Correction | Total |
|---|---|---|---|---|
| Byron 1995 Look-back to 1994 | 618 | 1.31 | Worse SG Analyzed | 809 |
| Byron 1996 Look-back to 1994 | 78 | 2.91 | 1.137 | 258 |
| Byron 1994 Detected and Repaired | 128 | n/a | All SG's | 128 |
| Total | | | | 1195 |

Note: 1186 indications were used in the EOC analysis, the difference in tubes is due to ECT data not copying

Table 3a. BOC Distributions for Average Volts for the POD, Look-Back, and EOC Approaches

| | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | NDE Distribution | BOC Distribution | BOC Distribution |
| 2 | Byron 1 | Byron 1 | Byron 1 | Braidwood 1 | Voltage at | POD Approach | Look-Back Approach | EOC Approach |
| 3 | Total Tubes for 1995 | Total Tubes for 1996 | Tubes Repaired in 1994 | Tubes Repaired in 10/95 | Top of Bin | SUM (Col. L) | SUM (Cols I+J+L). | SUM (Cols I+J+K) |
| 4 | | | | | | | | |
| 5 | 7 | 7 | 0 | 0 | 0.05 | 0 | 14 | 14 |
| 6 | 165 | 60 | 13 | 2 | 0.10 | 2 | 227 | 238 |
| 7 | 292 | 74 | 36 | 1 | 0.15 | 1 | 367 | 402 |
| 8 | 163 | 54 | 32 | 3 | 0.20 | 3 | 220 | 249 |
| 9 | 88 | 23 | 17 | 6 | 0.25 | 6 | 117 | 128 |
| 10 | 38 | 10 | 13 | 4 | 0.30 | 4 | 52 | 61 |
| 11 | 26 | 13 | 8 | 2 | 0.35 | 2 | 41 | 47 |
| 12 | 9 | 7 | 2 | 1 | 0.40 | 1 | 17 | 18 |
| 13 | 5 | 3 | 5 | 1 | 0.45 | 1 | 9 | 13 |
| 14 | 11 | 0 | 1 | 2 | 0.50 | 2 | 13 | 12 |
| 15 | 4 | 0 | 0 | 1 | 0.55 | 1 | 5 | 4 |
| 16 | 0 | 0 | 0 | 0 | 0.60 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0.65 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0.70 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0.75 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0.80 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0.85 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0.90 | 0 | 0 | 0 |
| 23 | 0 | 0 | 1 | 0 | 0.95 | 0 | 0 | 1 |
| 24 | | | | | | | | |
| 25 | 808 | 251 | 128 | 23 | <<SUM>> | 23 | 1082 | 1187 |
| 26 | | | | | | | | |

Table 3b. BOC Distributions for Maximum Voltage for the POD, Look-Back, and EOC Approaches

| | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | NDE Distribution | BOC Distribution | BOC Distribution |
| 2 | Byron 1 | Byron 1 | Byron 1 | Braidwood 1 | Voltage at | POD Approach | Look-Back Approach | EOC Approach |
| 3 | Total Tubes for 1995 | Total Tubes for 1996 | Tubes Repaired in 1994 | Tubes Repaired in 10/95 | Top of Bin | (Col. L) | SUM (Cols I+J+L) | SUM (Cols I+J+K) |
| 4 | | | | | | | | |
| 5 | 0 | 3 | 0 | 0 | 0.10 | 0 | 3 | 3 |
| 6 | 71 | 27 | 7 | 0 | 0.20 | 0 | 98 | 105 |
| 7 | 288 | 97 | 19 | 1 | 0.30 | 1 | 386 | 404 |
| 8 | 217 | 47 | 21 | 3 | 0.40 | 3 | 267 | 285 |
| 9 | 114 | 40 | 34 | 2 | 0.50 | 2 | 156 | 188 |
| 10 | 54 | 27 | 16 | 4 | 0.60 | 4 | 85 | 97 |
| 11 | 32 | 3 | 8 | 5 | 0.70 | 5 | 40 | 43 |
| 12 | 17 | 3 | 9 | 1 | 0.80 | 1 | 21 | 29 |
| 13 | 11 | 3 | 6 | 3 | 0.90 | 3 | 17 | 20 |
| 14 | 3 | 0 | 2 | 0 | 1.00 | 0 | 3 | 5 |
| 15 | 1 | 0 | 2 | 1 | 1.10 | 1 | 2 | 3 |
| 16 | 0 | 0 | 1 | 2 | 1.20 | 2 | 2 | 1 |
| 17 | 0 | 0 | 0 | 0 | 1.30 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 1 | 1.40 | 1 | 1 | 0 |
| 19 | 0 | 0 | 2 | 0 | 1.5 | 0 | 0 | 2 |
| 20 | | | | | | | | |
| 21 | 0 | 0 | 1 | 0 | 4.2 | 0 | 0 | 1 |
| 22 | | | | | | | | |
| 23 | 808 | 250 | 128 | 23 | << SUM >> | 23 | 1081 | 1186 |
| 24 | | | | | | | | |
| 25 | | | | | | | | |

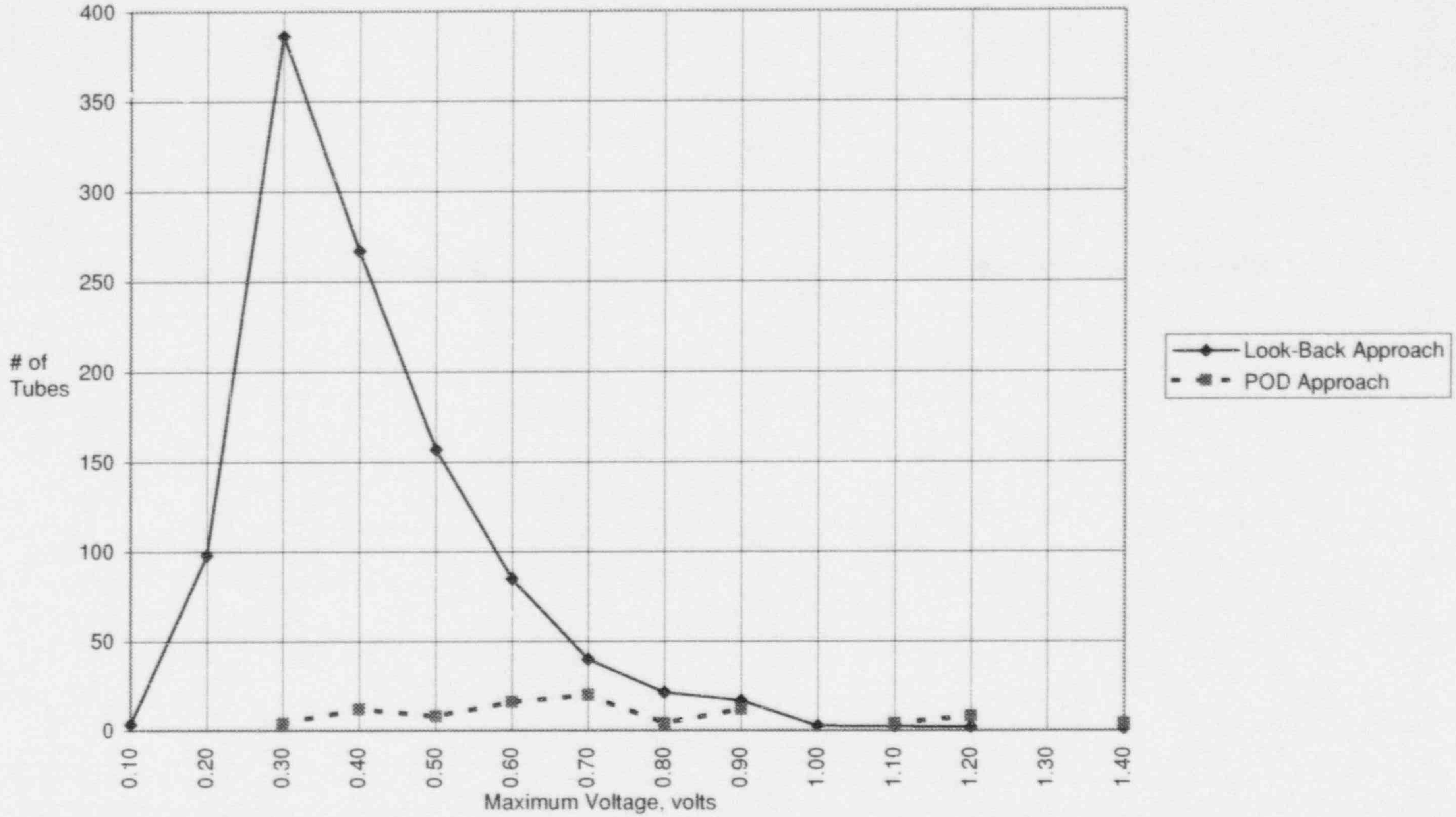
Table 4a. EOC Distributions for Average Voltage for the POD, and Look-Back Approaches

| | Distributions of Average Voltages | |
|---|---|---|
| Voltage at | ****************# Tubes **************** | |
| Top of Bin | Distribution for POD Approach | Distribution for Look-Back Approach |
| 0.05 | 0.000 | 2.280 |
| 0.10 | 1.520 | 58.340 |
| 0.15 | 3.430 | 149.150 |
| 0.20 | 7.250 | 178.080 |
| 0.25 | 10.790 | 178.470 |
| 0.30 | 12.060 | 156.850 |
| 0.35 | 11.960 | 118.550 |
| 0.40 | 10.140 | 78.950 |
| 0.45 | 8.890 | 53.910 |
| 0.50 | 6.590 | 37.110 |
| 0.55 | 5.460 | 25.790 |
| 0.60 | 3.970 | 17.240 |
| 0.65 | 2.560 | 10.160 |
| 0.70 | 1.590 | 6.820 |
| 0.75 | 1.520 | 4.120 |
| 0.80 | 0.900 | 2.400 |
| 0.85 | 0.460 | 1.390 |
| 0.90 | 0.350 | 0.950 |
| 0.95 | 0.220 | 0.410 |
| 1.00 | 0.110 | 0.320 |
| 1.05 | 0.080 | 0.190 |
| 1.10 | 0.050 | 0.200 |
| 1.15 | 0.020 | 0.140 |
| 1.20 | 0.000 | 0.050 |
| 1.25 | 0.030 | 0.040 |
| 1.30 | 0.010 | 0.040 |
| 1.35 | 0.030 | 0.010 |
| 1.40 | 0.000 | 0.010 |
| 1.45 | 0.010 | 0.010 |
| 1.50 | 0.000 | 0.000 |
| 1.55 | 0.000 | 0.000 |
| 1.60 | 0.000 | 0.000 |
| 1.65 | 0.010 | 0.010 |
| 1.70 | 0.000 | 0.000 |
| 1.75 | 0.000 | 0.000 |
| 1.80 | 0.000 | 0.000 |
| 1.85 | 0.000 | 0.000 |
| 1.90 | 0.000 | 0.010 |
| 1.95 | 0.000 | 0.000 |
| 2.00 | 0.000 | 0.000 |
| 2.05 | 0.000 | 0.000 |
| 2.10 | 0.000 | 0.000 |
| 2.15 | 0.000 | 0.000 |
| 2.20 | 0.000 | 0.000 |
| 2.25 | 0.000 | 0.000 |
| 2.30 | 0.000 | 0.000 |
| 2.35 | 0.000 | 0.000 |
| 2.40 | 0.000 | 0.000 |
| 2.45 | 0.000 | 0.000 |
| 2.50 | 0.000 | 0.000 |
| | | |
| | | |
| | | |
| | 90.01 | 1082.00 |

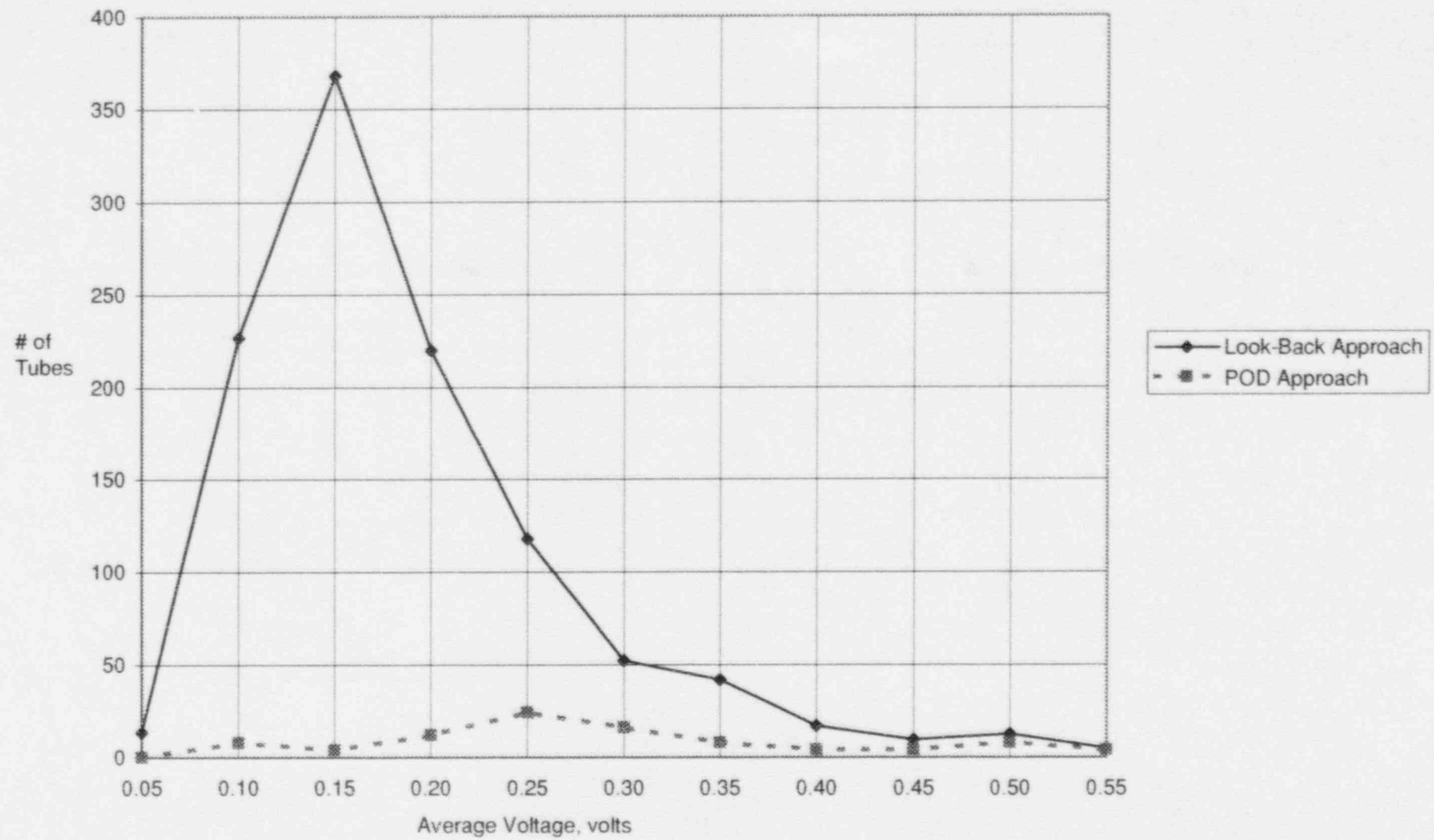
Table 4b. EOC Distributions for Maximum Voltage for the POD, and Look-Back Approaches

| | Distributions of Maximum Voltages | |
|---|---|---|
| Voltage at | ****************** # Tubes ****************** | |
| Top of Bin | Distribution for POD Approach | Distribution for Look-Back Approach |
| 0.10 | 0.00 | 0.55 |
| 0.20 | 0.04 | 23.36 |
| 0.30 | 1.21 | 96.15 |
| 0.40 | 3.06 | 156.01 |
| 0.50 | 6.40 | 178.73 |
| 0.60 | 8.52 | 170.87 |
| 0.70 | 10.22 | 145.72 |
| 0.80 | 10.64 | 108.58 |
| 0.90 | 9.67 | 75.33 |
| 1.00 | 8.47 | 49.87 |
| 1.10 | 7.47 | 30.49 |
| 1.20 | 6.05 | 18.17 |
| 1.30 | 4.43 | 11.20 |
| 1.40 | 3.93 | 6.10 |
| 1.50 | 2.82 | 3.74 |
| 1.60 | 2.01 | 2.27 |
| 1.70 | 1.45 | 1.27 |
| 1.80 | 0.94 | 0.76 |
| 1.90 | 0.92 | 0.76 |
| 2.00 | 0.55 | 0.41 |
| 2.10 | 0.34 | 0.20 |
| 2.20 | 0.33 | 0.17 |
| 2.30 | 0.16 | 0.06 |
| 2.40 | 0.12 | 0.06 |
| 2.50 | 0.07 | 0.05 |
| 2.60 | 0.07 | 0.02 |
| 2.70 | 0.02 | 0.04 |
| 2.80 | 0.03 | 0.01 |
| 2.90 | 0.01 | 0.02 |
| 3.00 | 0.00 | 0.00 |
| 3.10 | 0.03 | 0.01 |
| 3.20 | 0.03 | 0.01 |
| 3.30 | 0.00 | 0.00 |
| 3.40 | 0.00 | 0.00 |
| 3.50 | 0.00 | 0.00 |
| 3.60 | 0.00 | 0.01 |
| 3.70 | 0.01 | 0.00 |
| 3.80 | 0.00 | 0.00 |
| 3.90 | 0.00 | 0.00 |
| 4.00 | 0.00 | 0.00 |
| 4.10 | 0.00 | 0.00 |
| 4.20 | 0.00 | 0.00 |
| 4.30 | 0.00 | 0.00 |
| 4.40 | 0.00 | 0.00 |
| 4.50 | 0.00 | 0.00 |
| 4.60 | 0.00 | 0.00 |
| 4.70 | 0.00 | 0.00 |
| 4.80 | 0.00 | 0.00 |
| 4.90 | 0.00 | 0.00 |
| 5.00 | 0.00 | 0.00 |
| | | |
| | 90.02 | 1081.00 |

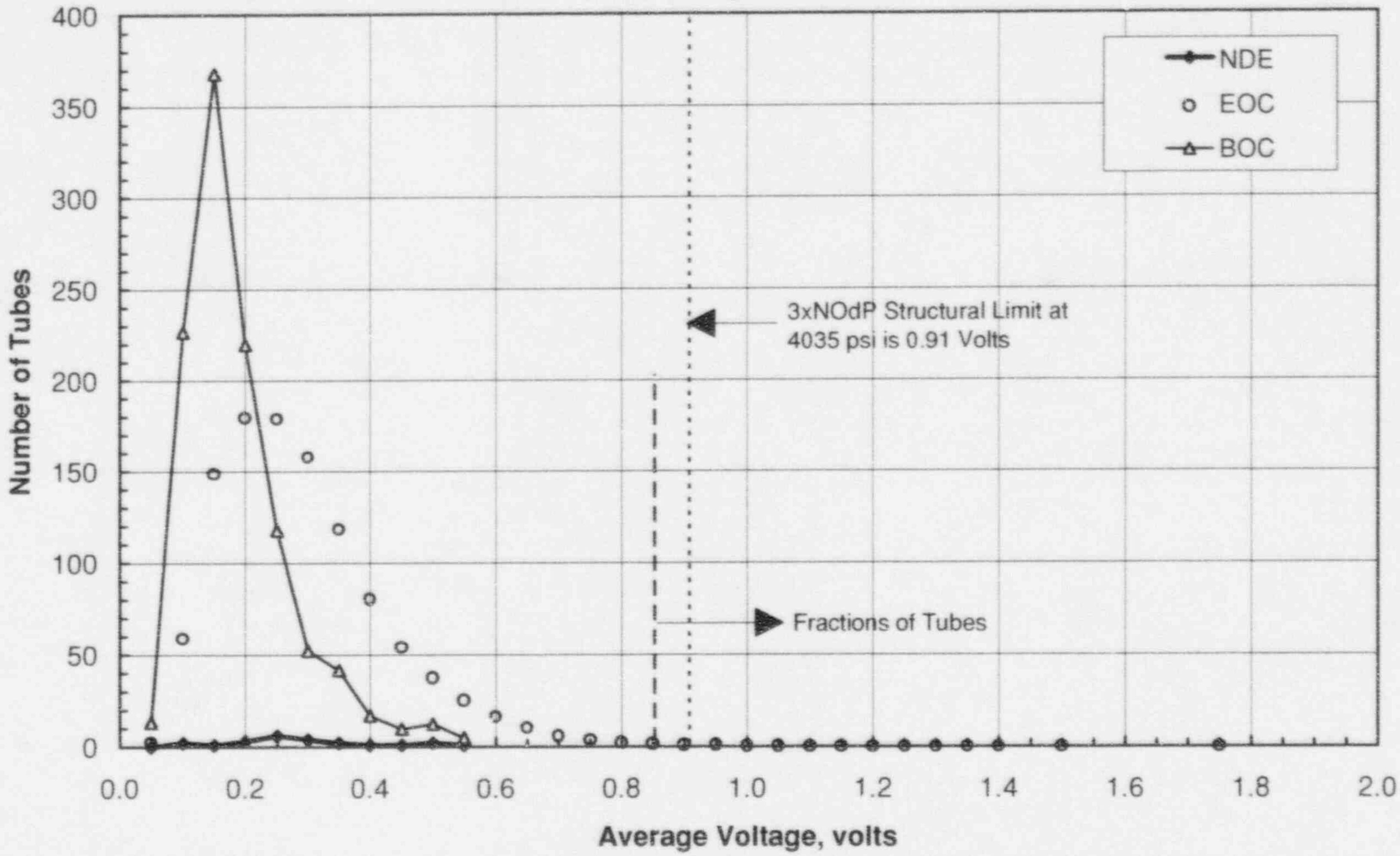
Braidwood 1 BOC-6 Comparison of Look-Back and POD Approaches Maximum Voltage
Figure 1



Braidwood 1 BOC-6 Comparison of Look-Back and POD Approaches Average Voltage Figure 2



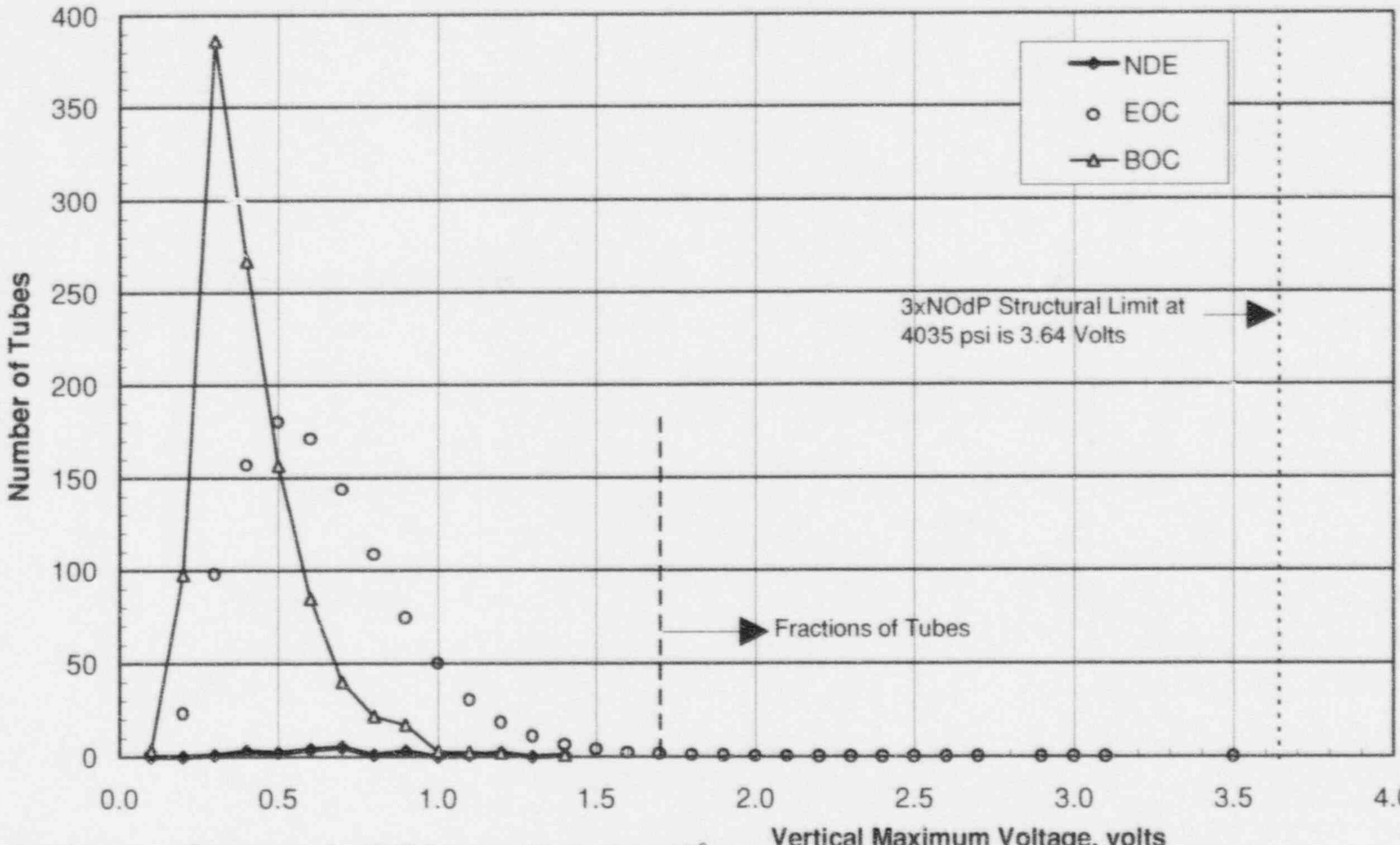
## Braidwood 461 Days EOC-6: Number of Tubes vs. Avg. Voltage Distribution
## Look-Back Approach
## Figure 3




**Conclusion:** 1. Frequency of tubes > 3xNOdP Structural Limit = $1.6 \times 10^{-3}$

2. Last whole tube is at 0.85 Volts

**Braidwood 461 Days EOC-6: Number of Tubes vs. Max. Voltage Distribution**
**Look-Back Approach**
**Figure 4**

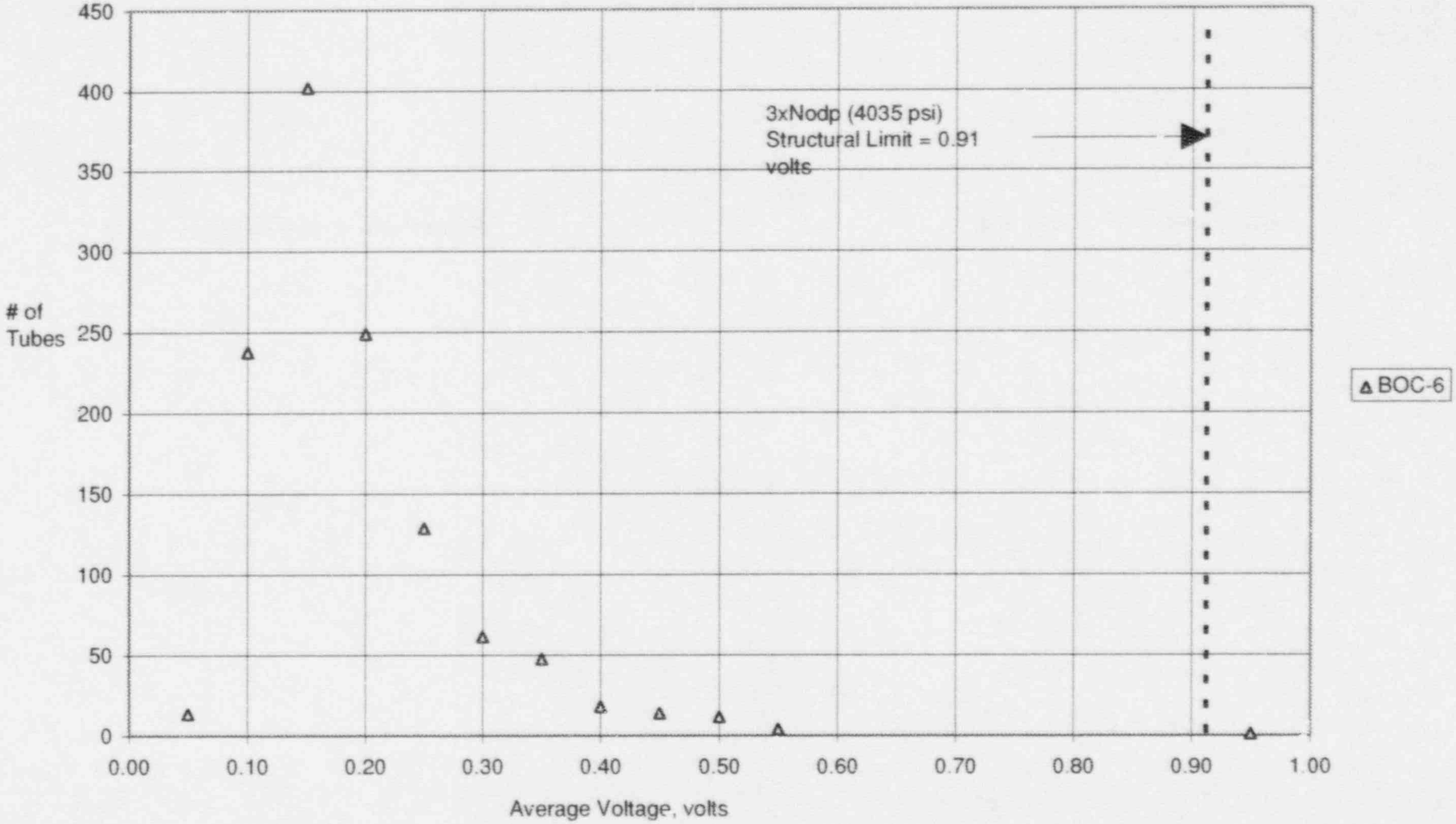



**Conclusion:** 1. Frequency > 3xNOdP Structural Limit = $9.3 \times 10^{-6}$
2. Last Whole Tube is at 1.7 Volts
3. Number of Tubes > 1.1 Volts Leakage Limit = 45

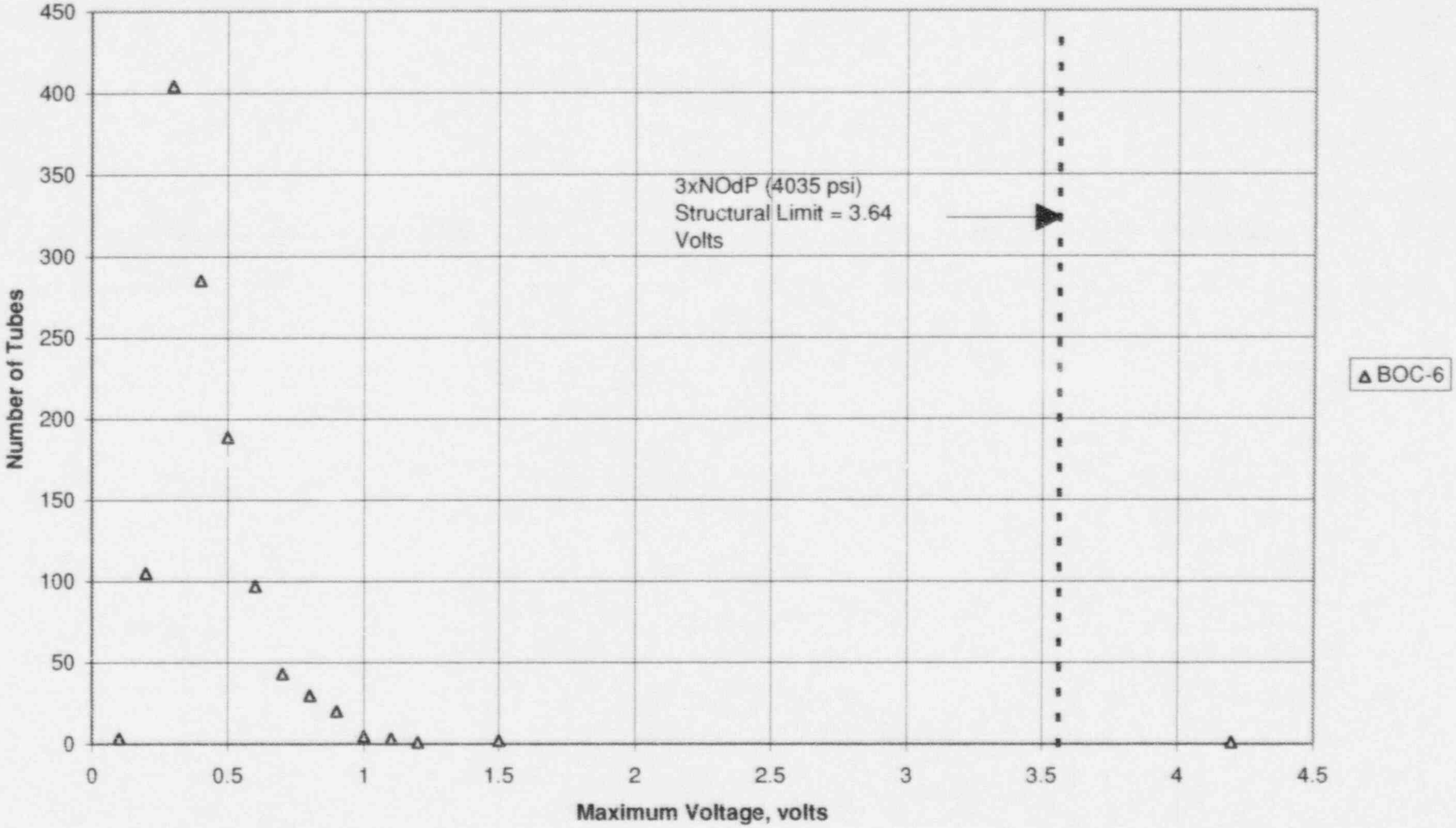
# Braidwood Cycle Length Evaluation Approaches
## Figure 5

| POD Approach | Look Back Approach |
|---|---|
| Braidwood EOC-5<br>23 Ind's, 0.080 Coil<br>No +point Exam.<br>4 SG's | Braidwood EOC-5<br>23 Ind's, 0.080 Coil<br>No +point Exam.<br>4 SG's |
| BOC-6 Distribution<br>Braidwood EOC-5<br>POD = 0.2<br>92 Ind's (1 SG) | BOC-6 Distribution<br>Braidwood EOC-5<br>Byron 95 & 96 Lookback to<br>94 (EOC-6), Limiting SG's<br>1082 Ind's (1 SG) |
| EOC-6 Distribution<br>GL 95-05 Methodology | EOC-6 Distribution<br>GL 95-05 Methodology |
| Limiting Burst Evaluation<br>SL = 0.91 Volts<br>Freq Tubes > SL = $6.6 \times 10^{-3}$<br>Avg Volts @ LWT = 0.80 | Limiting Burst Evaluation<br>SL = 0.91 Volts<br>Freq Tubes > SL = $1.6 \times 10^{-3}$<br>Avg Volts @ LWT = 0.85 |
| Leak Rate Evaluation<br>25 Tubes > Threshold<br>Leak Rate = 4 gpm | Leak Rate Evaluation<br>45 Tubes > Threshold<br>Leak Rate = 7.2 gpm |
| Conditional Burst Probability<br>POB Limit < $10^{-4}$<br>POB < 1.3 $10^{-5}$ | Conditional Burst Probability<br>POB Limit < $10^{-4}$<br>POB < 1.3 $10^{-5}$ |

**Braidwood 1 BOC-6: Number of Tubes vs. Average Voltage Distribution**
**EOC Approach**
**Figure 6**



**Braidwood 1 BOC-6: Number of Tubes vs. Maximum Voltage Distribution EOC Approach**
**Figure 7**



## ATTACHMENT B

## REQUEST FOR ADDITIONAL INFORMATION

## RELATED TO THE BRAIDWOOD, UNIT 1 CYCLE LENGTH ASSESSMENT

## BASED ON STEAM GENERATOR (SG) TUBE

## CIRCUMFERENTIAL INDICATION GROWTH RATES

## DOCKET NUMBER 50-456

1. **In the license's submittal dated August 2, 1996, a morphology assessment was provided which attempts to demonstrate the similarity between circumferential crack indications in Braidwood, Unit 1 to Byron, Unit 1 based on the relationship between the maximum and the average eddy current (EC) voltages. However, the licensee did not provide a sufficient basis the assuming in eddy current voltage assessment is indicative of degradation morphology. Accordingly, provide data supporting the assumption that circumferential flaws (either real and/or simulated) with morphologies different from that found at Byron 1 demonstrate a different and clearly distinct relationship between the average and the maximum EC voltage such that differing morphologies could be distinguished.**

Response:

Response to be provided in subsequent correspondence.

2. **In Section 4.3 of the licensee's submittal dated August 2, 1996, it is stated that Braidwood 1 growth rates had not been determined at the time of the submittal due to difficulty in converting the EC test data. State when this work will be completed and submitted to the NRC. If this conversion has been completed, submit the results of the assessment.**

Response:

Byron Unit 1 growth data has been used in assessment of Braidwood Unit 1 BOC-6 distributions because the Byron data is a statistically significant number of data points (over 750), meets the requirements of GL 95-05 and some of the growth rates span an entire operating cycle. Byron data for the two periods for which it was calculated (1994 to 1995 and 1994 to 1996) span long periods of operation (342 and 448 days > 500°F) minimizing the uncertainty in extrapolating the data to the proposed operating interval for Braidwood Unit 1 of 461 Days.

Two 0.080" RPC inspections have been performed at Braidwood Unit 1, one in February 1995 and one in October 1995 (EOC-5). The duration between the inspections is 202.74 days > 500°F.

Twenty three indications were detected and repaired in the October 1995 inspection. All 23 were present in the look-back to the February 1995 inspection. The growth rate data is calculated by subtracting the February 1995 voltage reading from the October 1995 voltage reading. The difference is then divided by the operating period (202.74 days) and multiplied by 365 to provide the growth rate per year. The growth rate data is then put at the top of 0.1 volts and 0.05 volts bins (e.g. 0.44 volts would be placed in the 0.5 maximum voltage bin and 0.45 average voltage bin), for maximum and average voltage growth, respectively. The growth rate results are shown in Figures 2a and 2b for maximum and average voltage, respectively.

Application of the EOC approach, discussed in the September 10, 1996 submittal (Attachment A), applies the Byron EOC-6 distribution to Braidwood directly without growth rates. This distribution provides for the entire population of indications in the worst SG at Byron, Unit 1 in 1994 (EOC-6) and therefore is conservative. The basis for concluding that this assumption is conservative is Braidwood Unit 1, in the Spring 1997, will have operated for a slightly shorter period than Byron Unit 1 in 1994.

3. **The licensee's assessment of Byron 1 growth rates considered inspection data from three inspection outages. Supply the growth rate data for each of the three intervals between these outages; i.e., the interval between the first and second SG tube inspections, the interval between the second and third inspection outages and the interval between the first and third inspection outages. Indicate which of the intervals exhibited the largest growth rate on an effective full power year (EFPY) basis. Provide these data in tabular form separated into the voltage bins shown in Figures 4.3 and 4.4 of your August 2, 1996 submittal. Explain how the indications were; placed in a particular bin. That is, state whether EC voltage values were truncated or rounded up to the higher voltage bin (e.g., 0.45 volts would be raised to 0.5 volts).**

Response:

Response to be provided in subsequent correspondence.

4. **Clarify the language in Section 4.2.2 of the text which states: "...one hundred three (103) indications identified during the 1994 EC inspection were re-analyzed with the 0.080 inch RPC probe."**

Response:

The statement refers to the scope of the voltage integral look-back re-analysis performed during June of 1996. During the re-analysis the indications detected and repaired in SG B and SG C in 1994 were re-analyzed. This total represents 103 indications. A total of 128 indications in all SG's were detected and repaired at Byron Unit 1 in 1994. Subsequent to issuing Braidwood Cycle Length Assessment Report dated August 2, 1996, the remaining 25 Byron Unit 1 1994 indications have been re-analyzed.

5. **Supply in tabular form, the data used in the burst pressure and leakage correlation's in the submittal dated August 2, 1996, including the following information: (1) the metallographic results (i.e., the percent degraded Area, the maximum depth circumferential extent), if available; (2) the SG tube material properties; (3) the EC voltage measurements (maximum and overage voltages) Indicating which inspection probe was used; (4) the maximum test pressure; and (5) the burst pressure and/or leak rate. As stated by the staff during the meeting held on August 26, 1996, some of the SG tube burst data in the correlation's relating EC voltage values to burst pressure may have come from SG tubes which burst axially rather than circumferentially. Identify in this table which data points in the correlation's burst axially as well as those that exhibited mixed mode cracking as determined from the destructive metallurgical examinations. Also, identify any indications that leaked during in-situ pressure testing at a rate beyond the pump capacity.**

Response:

Response to be provided in subsequent correspondence.

6. **Analytical predictions of circumferential burst pressure as a function of the percent of degraded SG tube area (PDA) are generally two-part correlation's. Specifically, a constant upper bound value dictates the axial burst pressure for SG tube, with limited degradation, However, more severely degraded tubes are governed by a relationship indicating lower circumferential burst pressures with increasing values of PDA. Since EC voltage may be related to PDA, it is possible that an empirical relationship between voltage and burst pressure may follow a trend similar to that predicted by analytical correlation's. The voltage-burst pressure relationship included in the submittal dated August 2, 1996, is a monotonically decreasing**

**function over all voltages. Discuss the basis for such a relationship in light of current analytical models for circumferential burst pressure.**

Response:

Response to be provided in subsequent correspondence.

7. **In Section 5.3 of the submittal dated August 2, 1996, it is stated that the assessment provided follows the methodology in NRC Generic Letter (GL) 95-05. However, a $2x10^{-2}$ frequency of indications greater than the structural limit is the proposed acceptance criteria as stated in Section 5.4. This latter value is twice the value given in GL 95-05. Accordingly, clarify the discussion on the basis for using this proposed acceptance criteria. In addition, provide a detailed discussion on the technical basis underlying the assumptions in the analysis which is intended to demonstrate that the conditional probability of burst for the SG tubes with voltage beyond the structural limit is less than about $10^{-4}$ when the frequency of indications is less than $2x10^{-2}$.**

Response:

Response to be provided in subsequent correspondence.

8. **Provide the basis for the shape of the curve used to determine the lower bound SG tube burst pressure. Determine whether a statistical fit to the data can be established using the available data set; i.e., the statistical fit should be valid at the 5% level consistent with GL 95-05. The guidance provided in GL 95-05 with respect to empirical models should be addressed; e.g., provide the order of the regression equation. If a statistical fit to the data can be established, provide a detailed probabilistic analysis of the conditional burst probability which is, consistent with the intent of GL 95-05.**

Response:

Response to be provided in subsequent correspondence.

9. **For any given EC voltage, a variety of flaw morphologies is possible. Since the staff believes that it has not been demonstrated that EC voltage can accurately predict the morphology of degradation as stated in Item 1 above, discuss the possibility that more structurally significant morphologies may exist than those used to determine the lower bound fit. For example, discuss the possibility that a very tight coplanar flaw with a 360m, 95-percent throughwall defect exhibits the same maximum EC**

**11. As discussed in Regulatory Guide 1.121. "Bases for Plugging Degraded PWR Steam Generator Tubes," SG tube repair criteria should consider the fatigue affects from cyclic loading forces. Discuss how these effects (e.g., fatigue, vibration, and flow-induced loadings) have been accounted for in the analysis of the proposed operating interval. Provide supporting test data.**

Response:

Response to be provided in subsequent correspondence.

**12. If a SG tube were to separate or burst, discuss the possibility that multiple failures could occur as a result of SG tube whipping or impingement. Provide the supporting data and analysis.**

Response:

Response to be provided in subsequent correspondence.

**13. Because of the non-coplanar nature of stress corrosion cracking in SG tube expansion transitions, EC signals from circumferential indications may exhibit both axial and circumferential degradation. Accordingly, discuss whether an assessment of SG tube degradation using voltage measurements from several scan lines (i.e., a volumetric assessment) is necessary as opposed to selecting a single scan line.**

Response:

Response to be provided in subsequent correspondence.

**14. The correlation of leak rate versus maximum EC voltage applies only to the end-of-cycle (EDC) EC voltage distributions derived from maximum EC voltages. Provide a similar relationship based on EC voltage integral measurements of circumferential indications. Describe, or reference if previously submitted, the procedure used to normalize the SG tube leak rates to the operating temperature and the main steam line break (MSLB) pressure of 2560 pounds per square inch (psi).**

Response:

Maximum voltage was selected as the parameter to assess leakage because it provides a good measurement of the crack's depth especially when the crack is asymmetric and a segment of the crack is either through wall or substantially deeper than the remainder of the crack front. Average

**voltage as one of the two data points connecting the lower bound curve but which may exhibit a lower burst pressure. Provide the supporting data. If different and/or lower burst pressures are possible for the same EC voltage, discuss how the proposed probabilistic analysis accounts for this uncertainty.**

Response:

Response to be provided in subsequent correspondence.

10. **The burst pressure data were corrected for Braidwood lower tolerance limit (LTL) properties using information from certified material test reports. To remain consistent with the methodology in GL 95-05, burst pressure data should be normalized using material property data from the industry database used for alternate plugging criteria applications for axial cracking at SG tube support plate intersections. Accordingly, adjust the data in Figures 5.5 and 5.6 of the August 2, 1996, submittal using the industry database and determine the resulting structural limits for the average and maximum EC voltage correlation's.**

Response:

The industry insitu pressure test and burst pressures have been corrected for industry LTL properties (95/95, 650°F). In the Braidwood Cycle Length Assessment Report dated August 2, 1996 the data was corrected for Braidwood Unit 1 LTL properties, plots of the industry data corrected for industry LTL properties are included as Figures 10a and 10b.

The correction factor for industry LTL properties is the ratio of the industry 95%/95% lower tolerance limit ($s_y + s_u$) to the industry room temperature mean ($s_y + s_u$) (EPRI Report, NP-6864-L, PWR Steam Generator Tube Repair Limits: Technical Support Document for Expansion Zone PWSCC in Roll Transitions - Rev. 2, August 1993).

$$130.65 \text{ ksi}/154.34 \text{ ksi} = 0.847$$

The insitu pressure test and burst pressures have been multiplied by this factor and the results plotted in Figures 10a and 10b against average and maximum voltage.

For the industry burst pressure tests corrected with the industry LTL properties the structural limit for average and maximum voltages at 3xNOdP (4035 psi) become 0.88 and 3.54 volts respectively. Previously reported plant specific structural limits were 0.91 and 3.64 volts respectively.

For plant specific application of the structural limits, the Braidwood Unit 1 LTL values will continue to be used in assessment of the Braidwood Unit 1 EOC distributions.

voltage provides a measure of the integrated degradation over the entire tube circumference and there may not be segments where the crack is either through wall or nearly through wall.

The industry leak rate data from insitu pressure tests and tube pull leak tests is plotted in Figure 14a against average voltage. The average voltage is normalized as discussed in Section 6.2.1 of the Braidwood Cycle Length Assessment Report dated August 2, 1996. A log-logistic probability of leak vs. average ECT amplitude function was developed. The probability of leak function is based upon the data presented in Section 7.0 of the Braidwood Cycle Length Assessment Report dated August 2, 1996. A 95% confidence level of the probability of leak function is used to assess the Braidwood Unit 1 EOC leak rate for the EOC approach for average voltage. Figure 14b shows the function and its lower 95% confidence level. Because a correlation between voltage and leak rate does not exist a maximum leak rate of (0.16 gpm) is assumed for each voltage bin.

Future analysis of circumferential indication distribution leak rate will continue to use maximum voltage, since it is the voltage parameter which provides the best indication of the depth of degradation.

Braidwood Unit 1 EOC leak rates are based upon leak rate testing performed at temperatures and pressures different from MSLB conditions. The test leak rates are corrected by the following procedure. Leak rate input data which are available and used to calculate a corrected leak rate at Braidwood MSLB conditions are: observed leak rate (room temperature), leak rate temperature and pressure, MSLB temperature and pressure, PICEP regression equations relating leak rate to pressure in terms of a ratio of the crack opening area to crack length. The most limiting ratio of the leak rate at MSLB temperature to room temperature is calculated using the most limiting (largest leak rate) crack opening to length ratio at MSLB pressure. From this ratio the leak rate at MSLB temperature is determined given the leak rate at test temperature. The PICEP computer code has been used by the industry for calculating MSLB leak rates in SG tubes.

**15. Assuming that the maximum EC voltage is a more accurate parameter for predicting SG tube leakage, discuss the need to assess the leakage from other portions of a circumferential SG tube indication which may have voltages that are less than the maximum EC voltage recorded for a given SG tube but that may nevertheless leak. Specifically, address the possibility that several locations in the circumferential crack pattern of a SG tube at the expansion transition may contribute to the overall leakage from the SG tube since it is possible that the individual cracks in a non-coplanar pattern could be separated by a sufficient distance such that separate EC voltages for these indications could be recorded.**

Response:

Response to be provided in subsequent correspondence.

**16. Given that for any EC voltage, a variety of morphologies can exist as discussed in Items 1 and 9 above, discuss the basis for assuming that there is an EC voltage cutoff for determining when a SG tube is susceptible to leaking. Discuss how the proposed methodology would account for the uncertainty in the potential for a SG tube to leak and the uncertainty in the leak rate itself. Further, given the limited amount of SG tube leakage data for circumferential indications, discuss why the bounding value of SG tube leakage which is assumed, is conservative.**

Response:

In order to provide additional conservatism in the leak rate analysis, to address limited data and uncertainties in the industry leak rate data, a log-logistic probability of leak vs. Maximum ECT amplitude function was developed. The probability of leak function is based upon the data presented in Section 7.0 of the Braidwood Cycle Length Assessment Report dated August 2, 1996. A 95% confidence level of the probability of leak function is used to assess the Braidwood Unit 1 EOC leak rate for the EOC approach. Figure 16 shows the function and its lower 95% confidence level. Because a correlation between voltage and leak rate does not exist a maximum leak rate of (0.16 gpm) is assumed for each voltage bin. Operating experience has demonstrated that circumferential cracks, even those with significant degradation, do not leak significantly under normal operating conditions. This is most likely due to the presence of ligaments observed from tube pull metallographic results. The leakage assumed in the analysis is the largest leakage (corrected to Braidwood MSLB conditions) measured during tube pull or insitu pressure leak testing and provides more realistic results than calculation approaches. The leak 0.16 gpm leak rate is applied to all voltage bins where leakage has been identified to occur. This conservatively applies the highest observed leak rate, corrected to MSLB conditions, to a distribution of indications which have been observed through testing to have significantly lower leak rates.

The EOC-6 leak rate will be calculated by summing the leak rate at each bin which is calculated as follows: obtain the product of the number of tubes in each bin and the probability of leak of tubes at the bin voltage then multiply by the bounding leak rate (from tube pull leak rate testing and insitu pressure testing).

This method will adequately account for uncertainties in the leakage data. Results of application of this method will be provided upon resolution of NRC questions on input parameters of the EOC analysis.

**17. Provide the EC inspection data and the calibration setup files used in the burst and leakage correlation's. In addition, provide EC data for a representative range of circumferential indications and their corresponding EC voltage integral and maximum EC voltage measurements. The EC data should be provided in a format compatible with Eddynet95 software.**

Response:

Response to be provided in subsequent correspondence.

**18. Provide a copy of the EC data analysis guidelines used during the Braidwood 1 SG tube Inspections in fall 1996.**

Response:

Response to be provided in subsequent correspondence.

**19. In Section 6.2.1 of the submittal dated August 2, 1996 the EC voltage normalization procedure for adjusting the SG tube burst and leakage data is described. This EC voltage adjustment was made to obtain consistent EC voltages for circumferential indications where the calibration standard did not contain an axial EDM notch. Discuss how the EC voltages for other reflectors in the calibration standard compare with the 0.58 correction factor applied to the data. Provide a statistical analysis based on field data which supports the use of the 0.58 correction factor.**

Response:

Response to be provided in subsequent correspondence.

**20. A 0.76 correction factor was applied to adjust 0.115-inch probe coil EC voltages to equivalent 0.080-inch probe coil EC voltages. Describe in detail the development of this correction factor, including a discussion on the number of samples reviewed, the types of defects analyzed, and the mean and standard deviation of the study sample. Additionally, provide the recorded EC voltages, if practical, or the range of circumferential indication EC voltages included in the sample. Provide a statistical analysis based on field data which supports the use of the 0.76 correction factor.**

Response:

Response to be provided in subsequent correspondence.

21. **Provide a summary of the essential variables of the inspection techniques as documented in the EC acquisition technique sheets (ACTS) and the analysis technique sheets (ANTS) for the Byron 1 SG EC inspections in 1994, 1995, and 1996 and for the 1995 Braidwood 1 SG EC inspections. Additionally, provide the ACTS and ANTS associated with the SG EC inspections conducted at other plants where data were obtained for use in the SG tube burst and leakage correlation's presented in the August 2, 1996, submittal. Identify and discuss how the differences in the acquisition and analysis of EC data will affect the EC voltage measurements used In the analysis.**

Response:

Response to be provided in subsequent correspondence.

22. **Some studies have identified a lift-off effect in SG tube expansion transitions for gimbaled probes due to SG tube geometry changes. This lift-off can decrease a probe coil's response to SG tube indications. If gimbaled probes were used in any of the inspections where data is used to support the Braidwood 1 cycle length assessment, explain the basis for not accounting for this affect for EC voltage measurements in expansion transitions. Some of the data in the SG tube burst and leakage correlation's were obtained from 56 tubes which had been explosively expanded into the SG tubesheet. Describe any differences between the transition geometry, particularly with respect to the length of the expansion of the explosively expanded tubes and that for roll- expanded SG tubes. Discuss the effects of the SG tube transition geometry on the recorded EC voltages. Discuss the need to account for liftoff in the EC voltage measurements for both the data used in the proposed correlation's and the data obtained for the field Indications**

Response:

Response to be provided in subsequent correspondence.

**23.** **In Figure 3.1 of the submittal dated August 2, 1996, the number of circumferential indications detected with the plus point coil is related to those detected with the 0.080-inch rotating pancake coil (RPC) probe. The results are presented as the number of indications as a function of EC voltages as measured with the plus point probe. Explain the relationship between the circumferential indication EC voltages as measured with the 0.080-inch coil to those measured using the plus point call. Describe the data sat used in the comparison study between the two coils. Explain the differences in the analysis guidelines for the coil study to those used during the Braidwood 1 AIR05 SG tube EC inspections. In addition, the EC voltages in this figure are the maximum indication EC voltages. State whether a similar relationship has been developed using average EC voltage (i.e., voltage Integral) measurements. If so, suppiy the results. If not, discuss the usefulness of performing such an assessment in light of the present analysis based an EC voltage integral measurements.**

Response:

Response to be provided in subsequent correspondence.

**24.** **Data to support the assessment of the probability of detection POD) and the SG tube burst and leakage correlation's in the August 2, 1996 submittal were taken from various sources. Since the noise levels inherent in the data and SG tube wall deposits way affect the resulting EC voltage measurements, provide an assessment comparing the influence of noise and deposits on the EC signals for the SG tube burst and leakage data. Additionally, provide a discussion as to how the noise levels were determined (i.e., SG tube location, coils, and frequencies). Given that these factors may affect EC voltage measurements, provide the basis for selecting the lowest point in the scan line as the null point for EC voltage measurements.**

Response:

Response to be provided in subsequent correspondence.

**25.** **In the Braidwood 1 cycle length assessment, analyst uncertainty values of 0. 19 and 0.22 were utilized. Given that a signal for a specific type of degradation may be better defined by one coil rather than another, provide an assessment of the analyst variability based on the coil of interest (e.g., the 0.080-inch robe). Additionally, state the units associated with these values. If the values are in volts, state the corresponding analyst uncertainty as a percentage value.**

Response:

Response to be provided in subsequent correspondence.

26. **Discuss the basis for keeping the data from the 100 SG tube and 200 SG tube tests separate for the analyst variability study, Provide and discuss the mean, standard deviation, and shape of the distribution used for the model of Analyst uncertainty (e.g., a normal distribution with a mean of x and standard deviation of y). Discuss the technical basis for the distribution which was used.**

Response:

Response to be provided in subsequent correspondence.

27. **Discuss the basis for reevaluating the EC voltages measured in the analyst variability study based an a resolution process. Discuss whether this practice was used in the blind tests. The staff believes that this method of analyzing analyst variability is inconsistent with the methodology used in GL 95-05 (i.e., reevaluating the EC voltages). Clarify what is meant by the statement that observation EC voltages from different coils for the same indications were excluded.**

Response:

Response to be provided in subsequent correspondence.

28. **Describe the measures included in the blind test protocol which would have prevented an analyst from using information from one coil to locate and size the maximum EC voltage signal as seen by another coil. As discussed by the staff in the meeting hold on August 26, 1996, the rotational slewing of the data via such mechanisms as the trigger offset feature in Eddynet95 could lead to additional variability in an analyst's ability to accurately size circumferential indications with an EC voltage integral measurement. Describe how this variability was accounted for in the assessment of analyst uncertainty.**

Response:

Response to be provided in subsequent correspondence.

29. **If the measured EC voltages in the "look back" analysis of the Byron 1 EC measurements were maximum EC voltages, explain the basis for applying these results of the analyst uncertainty measurement to the EC voltage integral measurements. If circumferential indications were sized using, the lissajous signal, explain the basis for applying a variability in sizing with the lissajous signal to measurements of maximum EC voltage determined by Positioning the signal cursor in the voltage integral scan.**

Response:

Response to be provided in subsequent correspondence.

30. **Provide a copy of the EC sizing procedures used in the assessments of the analyst uncertainty, the growth rate, the burst and leakage data, and the POD. Discuss the extent of use and the influence of the following on any EC voltage measurements: (1) the use of Eddynet95 data filters; (2) the trigger offset feature and (3) the presence of 360m circumferential flaws. Address both the EC voltage integral and the EC maximum voltage measurements.**

Response:

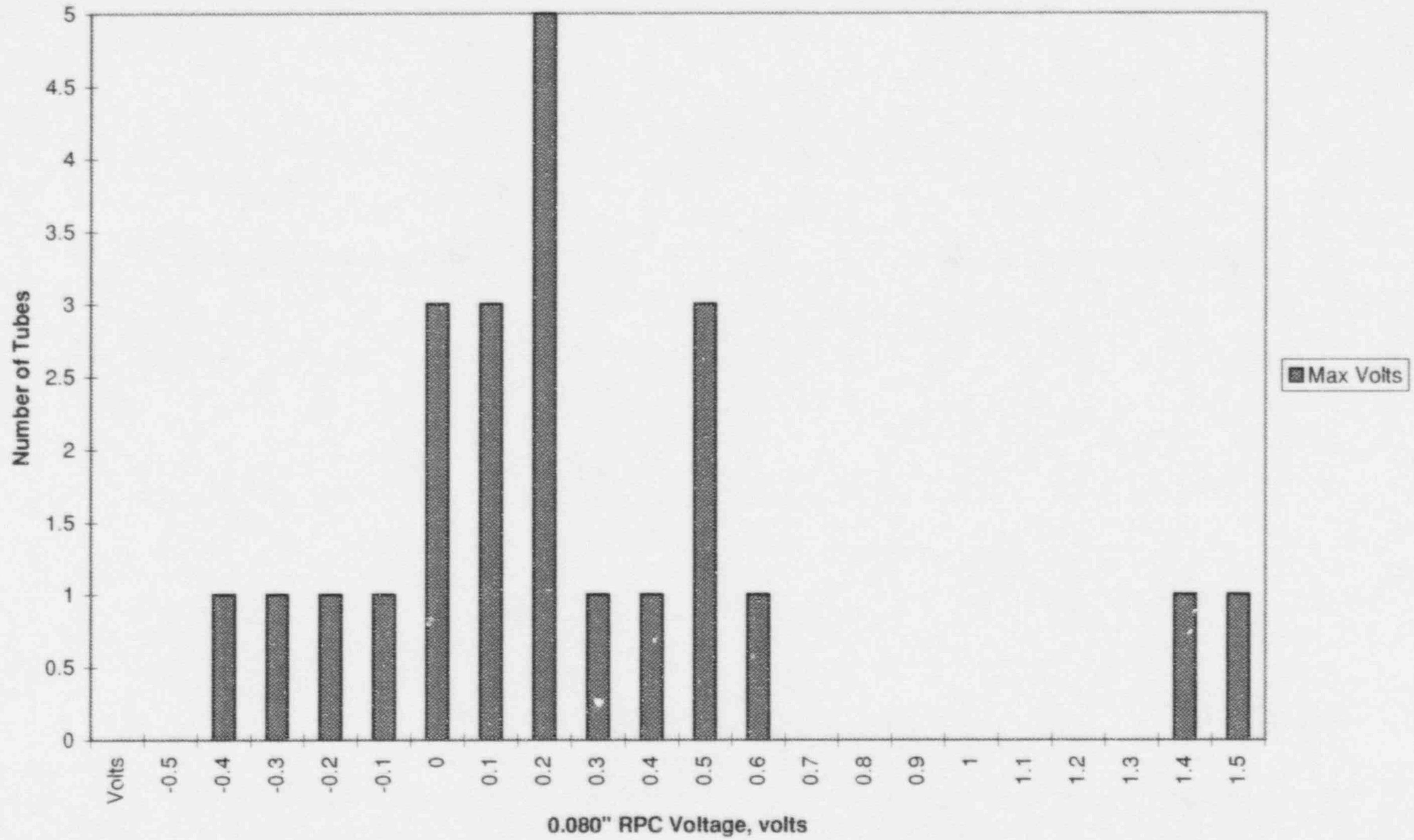
Response to be provided in subsequent correspondence.

31. **The probe wear allowance that was developed in the August 20, 1996 submittal was based on a small sample of the total SG tubes inspected. Provide an assessment of probe wear based on all available data. The staff believes that the methodology used to determine the probe wear allowance is significantly different from that used to determine the probe wear allowance in GL 95-05. Discuss the basis for not determining the probe wear allowance in accordance with the methodology used to support the GL 95-05 probe wear allowance given that different SG tube roughness can change the amount of probe wear observed between calibration runs.**

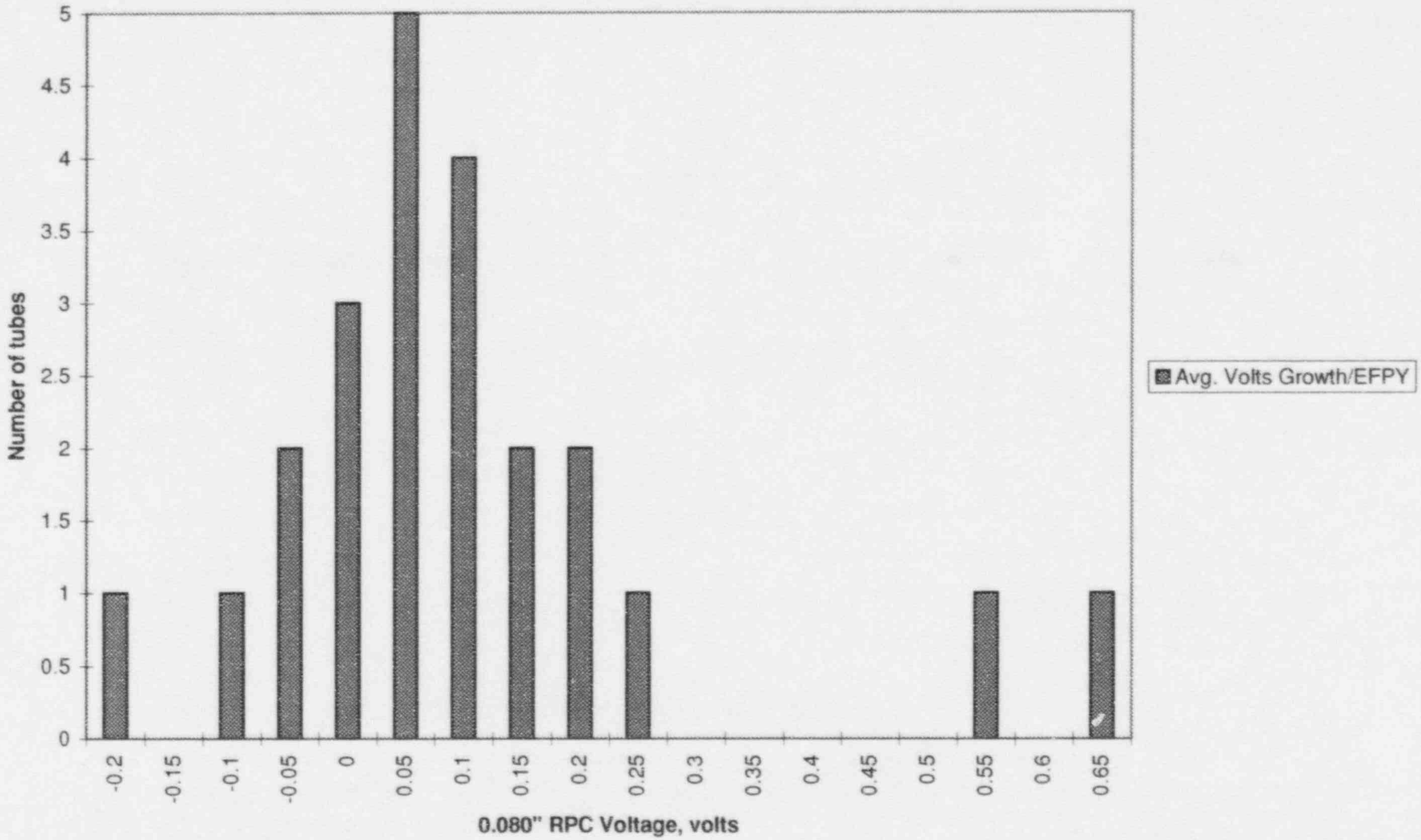
Response:

Response to be provided in subsequent correspondence.

Braidwood Unit 1 Maximum Voltage Growth 2/95 to 10/95
Figure 2a

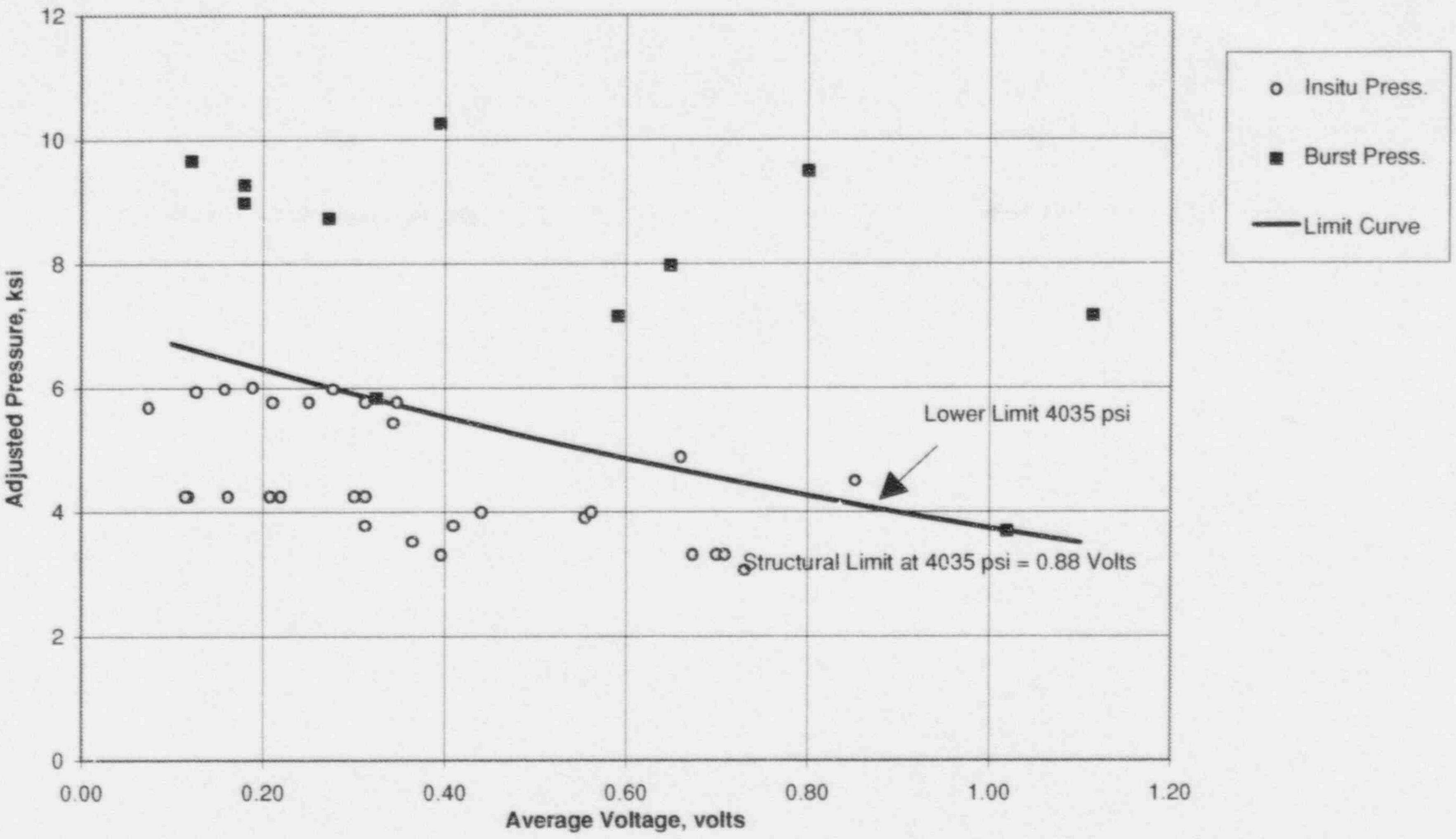


**Braidwood Unit 1 Average Voltage Growth 2/95 to 10/95**
**Figure 2b**

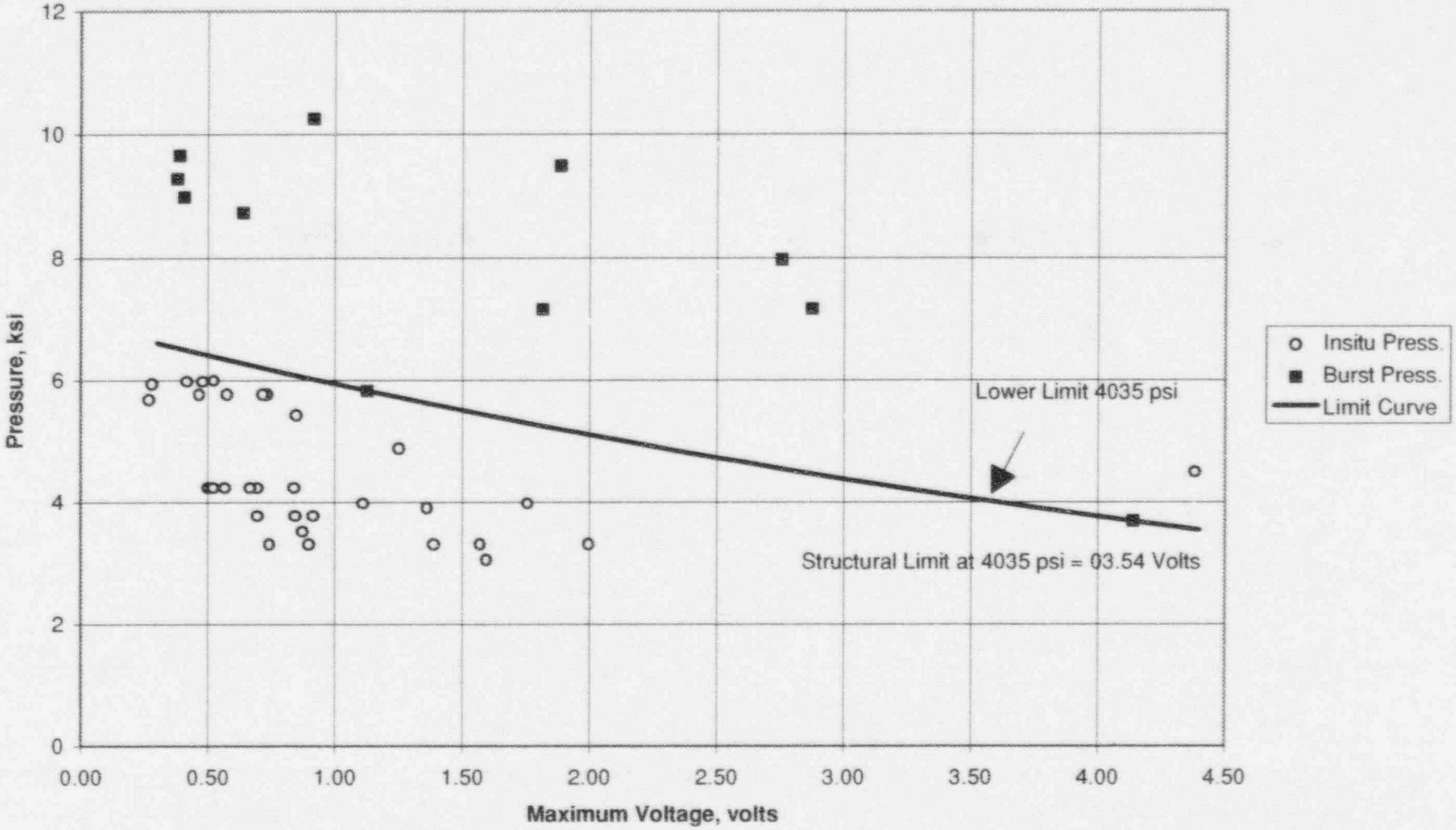


**Average Voltage vs. Adjusted Insitu or Burst Pressure Corrected to Industry LTL Properties (95/95 650F) Calculation**

**Figure 10a**



**Maximum Voltage vs. Adjusted Insitu or Burst Pressure Corrected for Industry LTL**
**Figure 10b**



**Average Voltage vs. Corrected Leak Rate at MSLB Conditions**
**Calculation Brw-96-456-M**
**Figure 14a**

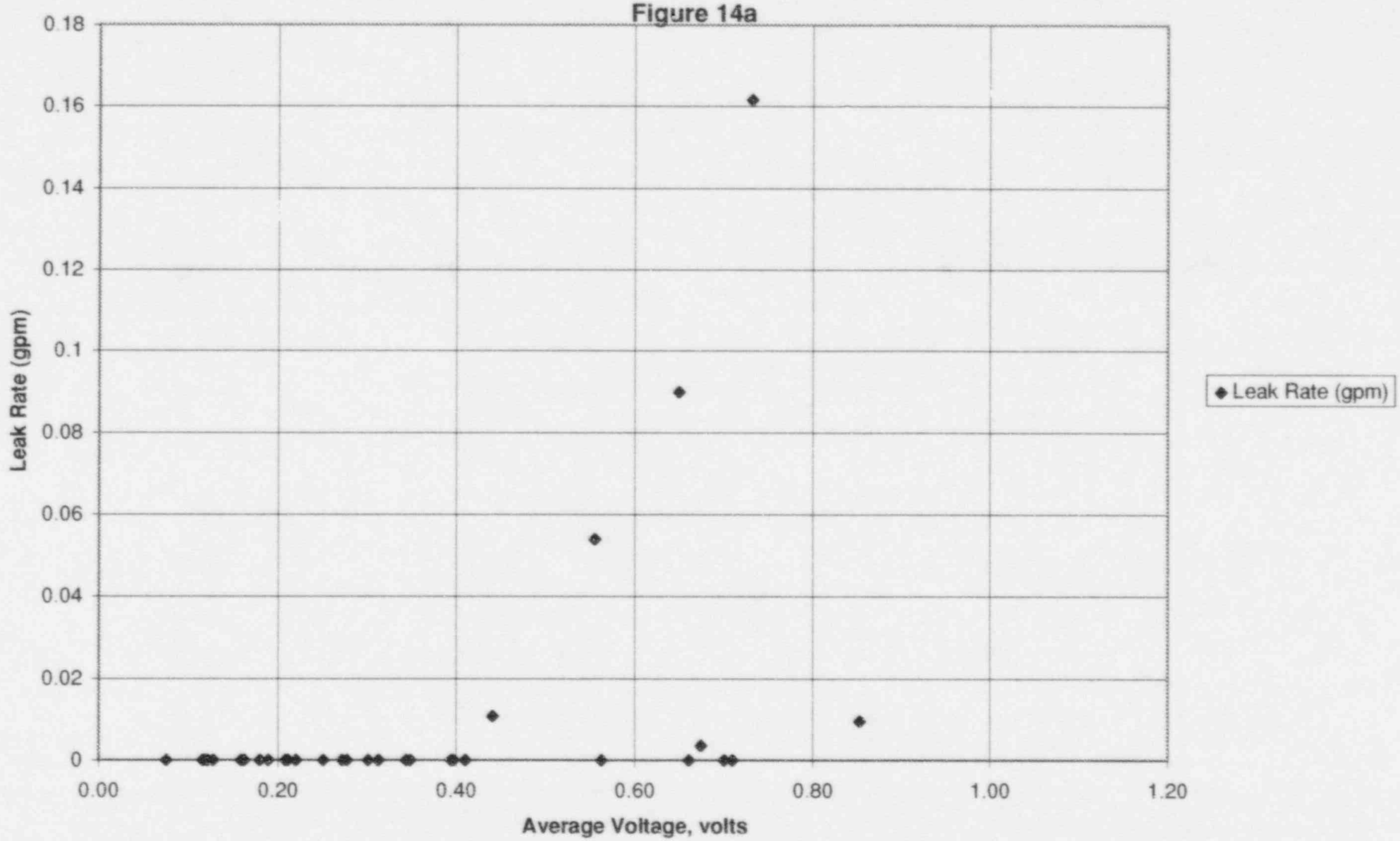


Figure 14b: **Probability of Leak vs. Average ECT Amplitude**
**(Commonwealth Edison Data)**

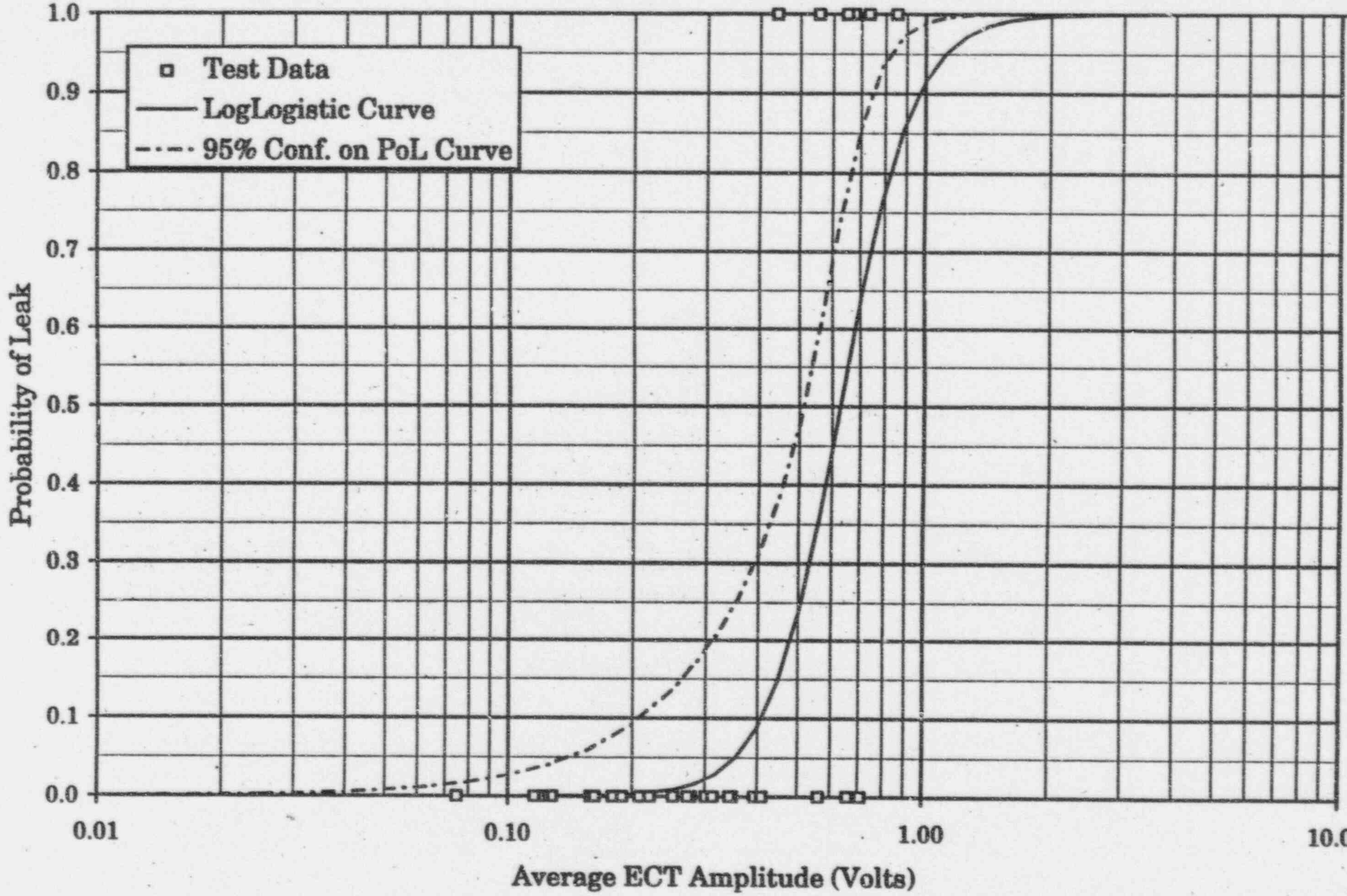


Figure 16: **Probability of Leak vs. Maximum ECT Amplitude**
**(Commonwealth Edison Data)**