NUCLEAR ENERGY INSTITUTE

David J. Modeen
DIRECTOR, ENGINEERING
NUCLEAR GENERATION DIVISION

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U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Steam Generator Degradation Specific Management Database, Addendum 3

PROJECT NUMBER: 689

References:

1. Letter from Jack R. Strosnider (NRC) to D. Modeen (NEI), "Industry Recommended Steam Generator Tube Pull Program," dated January 31, 2000
2. EPRI Report NP-7480-L, Addendum 3 and Enclosures, dated November 1999

The industry has carefully reviewed the NRC review comments (Reference 1) on the industry tube pull program described in Section 8 of Reference 2. Reference 1 indicated that the NRC staff has accepted most of the industry proposed modifications except for two items. These two items are addressed below with the industry proposed changes.

Regarding the industry proposed delay in tube removal by one outage if no pullable tube indications are found that would satisfy the industry target indications, the NRC staff has suggested that an exception should be made for the situation where tube pull specimens have not been obtained either during the plant steam generator inspection outage that implements the voltage based repair criteria or during an inspection outage preceding the initial application of these criteria. This is acceptable to the industry and the revised Section 8 of Update 3 (Enclosure 1) has been modified to reflect this change.

Regarding the industry proposal that for small indications leak tests do not need to be performed if the field and post-pull non-destructive testing data clearly show crack depths not greater than 85%, the NRC staff has expressed disagreement and suggested that the generic letter guidance should continue to be followed. The industry accepts this suggestion and this proposal has been deleted in the modified tube pull program described in the revised Section 8 of Update 3.

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One additional clarification has been added: Deplugged tubes should not be used to satisfy the tube pull requirements. NRC approved this clarification for Beaver Valley.

Enclosure 2 reproduces all of the NRC staff comments and summarizes the industry proposed modifications in italics. Since the industry has incorporated all of the NRC comments, we will assume that the tube pull program can be implemented as described in Enclosure 1 unless we hear otherwise from the NRC by the end of June 2000.

The other issues that need NRC review and approval are given below in order of decreasing priority.

1. Voltage dependent probability of detection (POD) described in Addendum 2 and Addendum 3 updates.

2. Addendum 2 voltage dependent growth rate methodology: A methodology is required to assess the GL 95-05 guidance that growth rates be evaluated for voltage dependence.

3. Addendum 3 application of a bobbin to rotating pancake coil (RPC) voltage correlation for dents > 5 volts to determine bobbin voltages for indications detected only by RPC.

The NRC's initial schedule for completion of its review of these issues is not being met. Several utilities have indicated a desire to use voltage dependent POD during the Fall 2000 outages. We would appreciate a revised schedule that supports the anticipated industry needs.

As has been the past practice, we believe any NRC staff review of the enclosed information is exempt from the fee recovery provision contained in 10 CFR Part 170. This submittal provides information that might be helpful to NRC staff when evaluating licensee submittals provided in response to Generic Letter 95-05. Such reviews are exempted under §170.21, Schedule of Facility Fees. Footnote 4 to the Special Projects provision of §170.21 states, "Fees will not be assessed for requests/reports submitted to the NRC…[a]s means of exchanging information between industry organizations and the NRC for the purpose of supporting generic regulatory improvements or efforts."

We would be pleased to meet with you or provide any support necessary to expedite acceptance of the outstanding issues regarding the database. If you have any questions regarding the technical content of this letter, please contact Dr. Govinda Srikantiah of EPRI at (650) 855-2091.

Sincerely,

David J. Modeen

JHR/
Enclosures

c: Mr. Ted Sullivan, U.S. Nuclear Regulatory Commission
Mr. Jim Andersen, U.S. Nuclear Regulatory Commission
Mr. Stewart L. Magruder, Jr., U.S. Nuclear Regulatory Commission

Enclosure 1

8 *(Rev.2)*

NDE, ANALYSIS METHODS AND PROGRAM UPDATES

8

NDE, ANALYSIS METHODS AND PROGRAM UPDATES

This section provides recommended updates to NDE and analysis methods applied in application of the ARC for ODSCC at TSP intersections. In inspections, ODSCC indications are sometimes found by RPC or + Point inspections that have not been reported by the bobbin inspection. The RPC indications may be found as part of the GL 95-05 required inspections of dented intersections or mixed residual intersections and possibly as a result of inspecting the intersection for other causes. Methods of inferring the bobbin voltage for these indications is desired for including the indications in the ARC burst probability and leak rate analyses and potentially to identify the need for repair of the indications. Two methods for determining bobbin voltages given that a RPC indication has been detected are given in Section 8.1.

The pulled tube database supporting the voltage based repair limits has been significantly increased since the issuance of GL 95-05. It is therefore appropriate to update the requirements for pulling tubes in support of the ARC. The industry recommended requirements for pulling tubes are given in Section 8.2.

8.1 Determination of Bobbin Voltages for Indications Detected Only by RPC Inspection

8.1.1 Background

Currently, GL 95-05 requires that ODSCC indications found by RPC (or equivalent probe such as + Point) as a result of inspecting intersections for copper deposits, dents greater than 5 volts and large mixed residuals that could cause a 1.0 volt bobbin signal to be missed or misread are to be repaired. GL 95-05 does not require indications found in dents < 5 volts or mixed residuals that do not mask a 1.0 volt bobbin flaw signal to be repaired. In these cases, the indications have not been detected by the bobbin coil and a bobbin voltage is not directly available for the indications. In addition to the inspection cases identified in GL 95-05, ODSCC indications at TSP intersections may be found as a result of RPC inspections for dents less than 5 volts and as a result of inspecting the TSP intersections for other causes. The latter could include the use of the TSP intersection as a locating position for inspection of freespan indications. It is desirable to obtain bobbin voltages for these ODSCC RPC indications in order to include the indications in the SLB burst probability and leak rate analyses and to determine the potential need for tube repair. The need for tube repair could be a resulting bobbin voltage greater than the repair limit or greater than one volt at a mixed residual.

One method for determining bobbin voltages for dents less than about 5 volts is based on identification of the flaw in a lower frequency channel (increased sensitivity to OD degradation) and reading the mix voltage for the identified flaw. A second means of inferring bobbin voltages from the RPC data is to develop a correlation between bobbin voltage and RPC voltage. A correlation can be reasonably expected since both voltages are primarily dependent upon the response to the deepest part of the indication.

8.1.2 Bobbin Voltages Obtained from Flaw Identification at Single Frequencies Such as 200kHz

The 200 kHz channel, or alternate single frequency such as 400 kHz, can sometimes be used to identify the flaw when the OD degradation found by RPC inspection cannot be identified in the prime/quarter frequency differential process channel (400/100 kHz for 7/8" tubing and 550/130kHz for ¾" tubing). For many flaws at dents less than 5 volts, the flaw can be identified by evaluating the 200 kHz channel for a flaw-like response. A peak to peak voltage measurement is then made on the flaw-like response at 200 Khz (or alternate single frequency). The flaw segment ("dots" in lisajous analysis) viewed without reevaluation in the prime/quarter frequency mix channel is recorded to obtain the reference bobbin voltage for the indication. The application of this technique for determining the mix voltage is limited to dents ≤ 5 volts. When the RPC flaw can be identified for bobbin sizing by this technique at non-dented intersections or mixed residuals, the technique may also be applied for these cases. Indications found in dents > 5 volts, indications that have a resulting bobbin voltage greater than the repair limit and indications found in mixed residuals that have a resulting bobbin voltage > 1.0 volt must be repaired.

8.1.3 Bobbin Voltages Inferred from Correlation of Bobbin Voltage to RPC Voltage

A general method for inferring bobbin coil voltages for indications found by RPC inspection but not identifiable in the bobbin data is based on application of a correlation between bobbin coil and RPC voltages. This method does not depend upon identification of a flaw-like response in the 200 kHz channel and can be applied for any RPC indication independent of dent size or mixed residual size. However, to maintain consistency with GL 95-05 requirements that indications found in dents > 5 volts are to be repaired, the applications of this technique are separated for dents ≤ 5 volts and for dents > 5 volts. This section describes a method for obtaining a correlation. A bobbin-to-RPC voltage correlation obtained using data for a plant with 7/8" tubes is included as an example, although not considered to be a generic correlation.

A database containing both bobbin voltage and RPC voltage for ODSCC indications is needed to develop the desired regression correlation between the bobbin and RPC voltages. Only data points with a RPC voltage between about 0.1 to 3 volts are of interest since voltages below about 0.1 volt are difficult to size, thus have a significant uncertainty, and indications above about 3 volts are beyond the range of interest (i.e., clearly require tube repair). Also, since the data outside the above voltage range are relatively sparse, variability in a few data points at the tail of the correlation could distort the correlation. Multiple axial indications with more than one deep flaw having significant RPC voltages should also be excluded since such indications could distort the correlation.

The ARC databases for 7/8" and 3/4" tubes were examined for developing generic bobbin-to-RPC voltage correlations for 7/8" and 3/4" plants. RPC voltages are available for only about 50% of the tube specimens in both these databases, and among those tube specimens, only 50% of the RPC voltages fall within the range of interest (0.1 to 3 volts). Hence, only about 25% of the data in the ARC database may be used to develop a correlation between bobbin coil and RPC voltages, and such a database is considered too small to yield a reliable correlation. Therefore, at present it is not feasible to develop a generic bobbin-to-RPC voltage correlations for 7/8" and 3/4" tube plants. However, historical data from EOC steam generator inspections may be used to develop a plant-specific correlation. Development of a correlation between bobbin and RPC voltages based on plant operational data is described below.

Description of a Prior Plant-Specific Analysis. Historical data from a plant with 7/8" diameter tubes were used to develop a correlation between the bobbin and RPC voltages. The RPC voltage data considered were obtained from 80 mil pancake coil probes. It is expected that pancake coil voltage data would correlate better with bobbin voltage data than +Point voltage data, although adequate +Point data are not yet available for an evaluation to confirm this expectation. The method of least squares was used to obtain a correlation between the bobbin voltage and RPC voltage amplitudes. Both linear and logarithmic forms of the variables were considered to determine the optimum combination of variables. The bobbin voltage versus RPC voltage data were plotted considering all four possible combinations of variable forms, and the data distributions were examined. A fifth case wherein the intercept for the linear bobbin to RPC correlation is forced to be zero was also considered. The data distribution did not suggest outright elimination of any of the variable combinations. Therefore, least squares regression analysis was performed for all five relationships. In addition, sensitivity analyses were performed for the range of RPC volts included in the correlation.

Table 8-1 provides a summary of the regression results. The square of the correlation coefficient (r^2, also called Index of Determination) and the p-values for the slope parameter in the regression are shown. The p-value for all five correlations considered are very small and they meet the 5% criteria recommended in Generic Letter 95-05 for an acceptable correlation. The r^2 values in Table 8-1 suggest a linear relationship between RPC voltage and bobbin voltage as shown below.

$$V_b = b_0 + b_1 V_{r80}, \qquad (1)$$

where V_b represents the bobbin amplitude and V_r represents the RPC voltage amplitude.

Analyses were performed to assess the sensitivity of the correlation r^2 and the RPC volts at 2 bobbin volts to the RPC voltage range used in the correlation. The data of Figure 8-1 suggest that a range between 0.2 and 2.0 RPC volt might be more appropriate for the correlation than the 0. 1 to 2.0 volts range used. Table 8-2 provides the results of the sensitivity study. It is seen in the table that r^2 does not significantly change for the 0.2 to 2 volt range but is notably reduced for the smaller RPC voltage intervals with a smaller database. The RPC voltage at 2 bobbin volts from the mean regression line does not change significantly between the correlations. Larger differences could be expected when confidence levels are added due to changes in the database size, but the mean correlation value at 2 bobbin volts appears to be well defined by the correlation. Since there is little difference in the correlation between 0.2 to 2 volts and 0.1 to 3 volts, the latter was used for the correlation to reduce the potential need to extrapolate beyond the range of the correlation in field applications. The regression relationship along with the data used in the regression analysis are shown in Figure 8-1.

An analysis of the regression residuals was also performed to check if the assumptions inherent in the least square analysis apply. A plot of the residuals of the bobbin voltage versus the bobbin voltage obtained using the regression correlation was prepared for each of the 5 relationships examined. The residuals plot should show random scatter without suggesting any type of correlation. The data for all relationships examined show random scatter indicating that a correlation does not exist between the residuals and the predicted values, and that the variance of the residuals is uniform. Figure 8-2 shows the residual scatter plot for the linear relationship shown in Equation (1).

Another implicit assumption in the least square analysis is that the regression residuals are normally distributed. To confirm the validity of this assumption for each correlation relationships considered, the residuals were sorted in ascending order and then plotted against an ordinate representing cumulative percent value for a variable given by

1

$$100 \times \frac{(i - \frac{1}{2})}{n}$$

where n is the number of data points used in the regression and i is an index ranging from 1 to n. The data should fall approximately on a straight line if the residuals are normally distributed. The residuals for all 5 relationships considered approximate a straight line, thus indicating that the assumption of normal distribution for residuals is valid. Figure 8-3 shows the ordered residuals plot for the linear relationship shown in Equation (1).

Uncertainties in the Predicted Bobbin Voltage. The voltage predicted using the correlation described above provides a mean value for the bobbin voltage at a given RPC voltage. Since eddy current inspection and voltage-based repair limits are based upon the nominal voltage indicated by a bobbin probe, it is appropriate to use the mean value predicted with the regression correlation. To account for uncertainties in the predicted mean value, 95% confidence intervals for the mean were established and the upper 95% confidence bound on the mean was used to obtain a conservative bobbin voltage estimate at a given RPC voltage. A one-sided upper 95% confidence bound for the bobbin voltage is also shown in Figure 8-1. The difference between the upper, one-sided 95% confidence bound and the mean vary slightly with the RPC voltage (between 0.1 to 0.4 volt bobbin voltage in the RPC voltage range 0.2 to 3 volts). The use of the 95% confidence band reduces the RPC voltage that corresponds to 2 bobbin volts from 1.51 to 1.38 volts. The RPC voltage at 1 bobbin volt is reduced from 0.40 to 0.28 volts for the 95% confidence value.

Application of Regression Correlation. The RPC voltage corresponding to 2 volts bobbin voltage at the upper, one-sided 95% confidence bound on the mean can be used to define tube repair requirements as well as the threshold to determine the need for expansion of the augmented RPC inspection of dented intersections and mixed residual signals. The use of RPC voltage corresponding to 2 volts bobbin voltage is appropriate for mixed residuals or dented intersections since it is used to assess the significance of the detected indication by comparison with the repair limit. The curve representing the one-sided 95% confidence bound in Figure 8-1 can be represented by the following equation.

$$V_b \ = \ 0.77 + 0.82 \times V_{rpc} + 0.06 \times V_{rpc}^2 \qquad (2)$$

where V_b represents the bobbin voltage and V_{rpc} represents the RPC voltage. The above correlation is valid for RPC voltages between 0.1 to 3 volts. It is noted that Equation (2) is presented as an example, and it is not recommended as a generic correlation.

The above equation may be used to obtain equivalent RPC voltage at the repair limit. For the example case presented, the RPC voltage from an 80 mil pancake probe corresponding to 2 volts mean bobbin voltage is 1.38 volts.

Recommendations. When a correlation between the bobbin and RPC voltages can be developed on a plant-specific basis, the correlation can be applied to determine the need for tube repair based on the estimated bobbin voltage (corresponding to a measured RPC voltage). The ODSCC indications detected at dented or mixed residual intersections should be included in the tube integrity evaluations performed to support voltage-based repair criteria. A correlation similar to Equation (2) can be used to convert the RPC voltage measured for an ODSCC indication at dented intersections or intersections with large bobbin residual signals into an equivalent bobbin voltage for use in the tube integrity analyses. However, it is necessary to separate the application of the correlation for consistency with the GL 95-05 requirements on dents as given below:

Application to Dents ≤5 Volts and Mixed Residuals

- Bobbin voltages are to be inferred from the bobbin to RPC voltage correlation at 95% confidence on the mean correlation.
- Bobbin voltages inferred from RPC volts by application of a correlation are to be included in the condition monitoring and operational assessments for burst probability and SLB leak rate calculations.
- Bobbin voltages greater than the ARC repair limit are to be repaired.
- Bobbin voltages greater than or equal to 1.0 volt found in a bobbin coil mixed residual signal are to be repaired.

Application to Dents > 5 Volts

Few indications have been found to date in dents > 5 volts. Bobbin voltages for indications found in dents < 5 volts have been small and have negligible influence on the ARC leak and burst analysis results. When found in > 5 volt dents, the indications could have larger bobbin voltages since bobbin coil detection of flaws in large dents would be expected to be significantly poorer than for small dents. Therefore, the application above 5 volts requires additional uncertainty considerations in the ARC leak and burst analyses as included in the following requirements for application of a correlation to > 5 volt dents:

- The bobbin to RPC voltage correlation must satisfy a p-value of < 5% for an acceptable correlation and bobbin voltages are to be inferred from the correlation at 95% confidence on the mean correlation.
- NRC approval for the application of a bobbin to RPC correlation is required since the application above 5 volt dents represents a deviation from GL 95-05.
- Bobbin voltages inferred from RPC volts by application of a correlation are to be included in the condition monitoring and operational assessments for burst probability and SLB leak rate

calculations. The uncertainty in the bobbin to RPC voltage correlation must be included in the leak and burst analyses.

- The requirements for tube repair based on the inferred bobbin voltages are the same as given above for dents < 5 volts.

8.2 Requirements for Pulling Tubes in Support of the Voltage Based Repair Limits

8.2.1 Description of the Issue

The pulled tube database supporting the voltage based repair limits has been significantly increased since the issuance of GL 95-05. It is therefore appropriate to update the requirements for pulling tubes in support of the ARC. This section describes industry recommended requirements for pulling tubes.

Pulled tubes are required to characterize the crack morphology as dominantly axial ODSCC for consistency with that of the EPRI database and to increase the pulled tube database supporting the ARC. There have been no pulled tubes for which the ODSCC crack morphology differs from that found in the initial EPRI database prior to issuance of GL 95-05. The morphology is dominantly axial ODSCC with differences between pulled tubes being principally in the degree of cellular corrosion found at a given intersection. The cellular involvement can differ between TSP intersections on the same tube as much as differences between SGs or plants. The only morphology difference from the EPRI database found in the pulled tubes has been one case of combined local wall thinning with ODSCC, which was identified as a volumetric indication in the field inspection and was pulled to clarify the morphology of the indication. Tubes pulled with RPC axial ODSCC field calls have had morphologies consistent with the EPRI database. Consequently, removal of tubes specifically for morphology verification can be a low priority for tube removal. As a result of this consistent morphology experience, it is acceptable to delay the initial tube pull for morphology confirmation to the end of the first cycle following ARC implementation if this delay can improve the value of the pulled tube data to the database.

The principal objective for the tube pulls should be to support the database where the database has limited data. The burst pressure versus bobbin voltage correlation has not changed significantly with additional pulled tube data since before issuance of GL 95-05 in 1995. The additional data have resulted in changes in the structural limit by about half a volt or less. Changes in the leak rate versus voltage correlation have been more significant due to the smaller database on leaking tubes. Thus the primary objective for pulling tubes should be to increase the leak rate database. The tubes should have a large enough voltage to have a significant likelihood of leaking. The correlations of Section 6 show that to obtain a 30% probability of leakage, a ¾ inch diameter tube should have a bobbin voltage > 3.2 volts and a 7/8 inch diameter tube should have a voltage > 6.5 volts. The leakage database for 7/8 inch tubing is not as extensive as that for ¾ inch tubing and the probability of leakage might be reduced to 20% which would require > 5 volts. These considerations lead to emphasis on pulling tubes based on having large enough voltages to contribute to the leak rate database.

The GL 95-05 requirements for tube removal can be summarized as follows:

1. Number and Frequency of Tube Pulls

- Two pulled tubes with a minimum of four intersections should be obtained during the plant SG inspection outage implementing the ARC or a preceding outage.

- Additional tube pulls with a minimum of two intersections should be obtained at the refueling outage following accumulation of 34 EFPM of operation following the previous tube pull.

2. Selection Criteria

- The emphasis should be on removing tube intersections with large voltage indications

- Where possible, the removed intersections should cover a range of voltages, including intersections with no detectable degradation.

- Selected intersections should include a representative number of intersections with RPC signatures of a single dominant crack as compared to intersections with two or more dominant RPC signatures around the circumference.

The following provides recommended changes to the above requirements for tube removal.

8.2.2 Bases for Tube Removal Guidelines

Based on the above considerations, the primary emphasis for pulled tubes should be to support the leak rate correlation, while also obtaining information on crack morphology. Table 8-3 summarizes the number of ODSCC indications pulled and destructively examined and the number of intersections that had leak rates contributing to the correlations for both ¾ and 7/8 inch diameter tubing. It is seen that 131 out of a total of 211 indications had voltages less than 2 volts. This voltage range, which is typical of indications found during the first outage implementing the ARC, has more data than needed and emphasis for tube removal should be on higher voltage indications. In this low voltage region, crack morphology features typically are not well established and the data provide only OD cracking as a morphology confirmation. Therefore, the tube removal requirements should be defined to minimize the need for pulling low voltage indications.

For ¾ inch tubing, indications greater than about 3 volts would have a 30% probability of leakage and would likely contribute to the leak rate correlation database. As seen in Table 8-3, the existing leak rate database for ¾ inch tubing is extensive and only 4 indications are needed to complete a database of 2 indications in each one volt bin up to 12 volts. For 7/8 inch tubing, indications less than about 4 volts have a very low leakage probability with only 1 small leaking indication in 41 pulled tube indications between 1 and 4 volts. The probability of leakage correlation shows about a 15% leakage potential at 4 volts. Therefore, indications > 4 volts are desirable to have a reasonable likelihood of contributing to the leak rate database. It is therefore recommended that tube pulls be targeted toward obtaining a leak rate database of 2 indications in each one volt range above a minimum of 2 volts for ¾ inch tubing and above 4 volts for 7/8 inch tubing. For additional information on 7/8" tubing, the final recommendation applies to indications above 3 volts.

8.2.3 Criteria for Tube Removal and Examination/Testing

Implementation of the voltage based repair criteria should include a program of tube removals for testing and examination as described below. The purposes of this program, in order of priority, are: 1) provide additional data to enhance the conditional leak rate, burst pressure and probability of leakage correlations; 2) confirm axial ODSCC as the dominant degradation mechanism at or near the time of ARC implementation; 3) assess inspection capability; and 4) monitor the degradation mechanism over time.

The principal database goal to support the ARC correlations is to enhance the leak rate correlation. Table 8-3 identifies voltage ranges for additional leaking indications (target number) to work toward a leak rate database that includes at least two indications with leakage in one volt intervals for which leakage is reasonably expected. Tube removals should be targeted toward satisfying the target number of indications. However, since indications that have been plugged and are deplugged for potential return to service may have voltage changes different from service related growth, deplugged tubes should not be removed to satisfy the ARC tube removal requirements. As noted below, the required times for tube pulls may optionally (utility option) be delayed up to one fuel cycle if no pullable tube indications are found that satisfy the target indication voltage ranges. The data of Table 8-3, including target indications, shall be updated and included in the EPRI ARC database addenda so that the target indications reflect the latest available pulled tube results.
The following criteria for tube removal and examination shall be followed (significant changes to NRC GL 95-05, Section 4 are underlined).

Number and Frequency of Tube Pulls

- Two pulled tube specimens with an objective of retrieving as many intersections as is practical (a minimum of four intersections) should be obtained for each plant either during the SG inspection outage that implements the voltage based repair criteria or during an inspection outage preceding initial application of these criteria. However, if no pullable tube indications are found in this inspection that would satisfy the industry database target indications, the tube removal may be delayed (utility option) to the next planned inspection with the goal of obtaining indications satisfying the database target. The tube pulls may not be delayed more than one planned outage following implementation of the repair criteria.

- On an ongoing basis, an additional (follow-up) pulled tube specimen with an objective of retrieving as many intersections as is practical (minimum of two intersections) should be obtained at the refueling outage following accumulation of three operating cycles following the previous tube pull. However, if no pullable tube indications are found in this inspection that would satisfy the industry database target indications, the tube removal may be delayed (utility option) to the next planned inspection with the goal of obtaining indications satisfying the database target. The tube pulls may not be delayed more than one planned outage following the required time for an additional pulled tube specimen. Consequently, the maximum interval between tube removals is four operating cycles to provide a periodic confirmation of crack morphology.

- If the above time requirements for a pulled tube specimen coincide with the plant's last scheduled outage before SG replacement, the requirement for a tube pull is waived. However, this waiver does not apply if the plant has not previously pulled tubes to support the ARC database. For example, if the last scheduled outage is the first or second outage implementing the ARC, the waiver does not apply where tube pull specimens have not been obtained during the plant SG inspection outage that implements the voltage based repair criteria or during an inspection outage preceding initial application of these criteria.

- If indications with unanticipated voltage levels substantially higher than the structural limit (for example, > 10 volts) from the burst correlation are found in an inspection, the indication should be considered for removal and destructive examination if the test results are likely to determine whether or not condition monitoring or operational assessment results would satisfy acceptance limits.

Tube Removal Selection Criteria

- The primary emphasis for selecting an intersection for removal should be an indication that satisfies the target indication voltages of Table 8-3. If the target voltage range cannot be satisfied, the emphasis should be on intersections with large voltage indications.

- Where possible, the removed tube intersections should cover a range of voltages, including intersections with no detectable degradation.

- For selection between indications of comparable voltage levels, the preference for removal should be intersections with RPC (or equivalent probe) signatures indicative of a single dominant crack as compared to intersections with RPC signatures indicative of two or more dominant cracks about the circumference.

Pulled Tube Examination and Testing

- Removed tube intersections should be subjected to leak and burst tests under simulated MSLB conditions to confirm that the failure mode is axial and to permit enhancement of the supporting data sets for the burst pressure and leakage correlations. The systems for leak testing should accommodate and permit measurements of leak rates as high as practical including leak rates that may be in the upper tail of the leak rate distribution for a given voltage. Leak rate data should be collected at temperature for the differential pressure loadings associated with the maximum postulated MSLB. When it is not practical to perform hot temperature leak tests, room temperature leak rate testing may be performed as an alternative. Burst testing may be performed at room temperature. The burst and leak rate correlations and/or data should be normalized to reflect the appropriate pressure and temperature assumptions for a postulated MSLB.

- Subsequent to burst testing, the intersections should be destructively examined to confirm that the degradation morphology is consistent with the EPRI database morphology for ODSCC at tube to TSP intersections. The destructive examination techniques should include techniques such as metallography and scanning electron microscope (SEM) fractography as necessary to characterize the degradation morphology (e.g., axial ODSCC, circumferential ODSCC, IGA involvement, cellular IGA and combinations thereof) and to characterize the largest crack networks with regard to their orientation, length, depth and ligaments. For uncorroded ligaments, the following information should be reported: location within the elevation of the overall macrocrack; angular orientation (approximate degrees) relative to the primary direction of the macrocrack; and size of the ligament such as uncorroded ligament area. The purpose of these examinations is to verify that the degradation morphology is consistent with the assumptions made in NRC GL 95-05 as well as that included in the EPRI database.

8.3 References

8-1 Westinghouse Report WCAP 14277 (Non-Proprietary), Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections," December 1996.

8-2 Addendum – 1 to EPRI Report, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates – Database for Alternate Repair Limits, NP-7480-L, August 1996.

8-3 Letter H. Gene Stanley, ComEd to USNRC, Document Control Desk, "Braidwood Unit 1 – 3 Volt IPC, Full Cycle Operation Technical Basis, Supplement to Braidwood Unit 1 Cycle 7 Interim Plugging Criteria Report," Braidwood Unit 1 NRC Docket Number 50-456, January 14, 1998.

8-4 EPRI Report NP-7480-L, Volume 2, Revision 1, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates – Database for Alternate Repair Limits, Volume 2: 3/4 Inch Diameter Tubing", August 1996

8-5 NRC Letter, Thomas H. Essig to David J. Modeen, NEI, "EPRI Report: "Proposed Data Exclusion Criteria and Adjustment of Measure Leak Rate for Tube R28C41 (Plant S)", February 26, 1998

Table 8-1

Summary of Alternate Bobbin to RPC Voltage Correlations
80 mil Pancake Coil RPC Data

Functional Form	Index of Determination, r^2	p-value for Slope Parameter	RPC Voltage[1] Corresponding to Bobbin 2 volt Repair Limit
Bobbin Voltage vs RPC voltage	47.3%	1.7×10^{-32}	1.51
Bobbin Voltage vs RPC Voltage (zero intercept)	21.4%	3.5×10^{-19}	Not Considered
Log_{10}(Bobbin) vs RPC Voltage	36.1%	4.8×10^{-26}	Not Considered
Log_{10}(Bobbin Voltage) vs Log_{10}(RPC Voltage)	38.4%	4.8×10^{-28}	Not Considered
Bobbin Voltage vs Log_{10}(RPC Voltage)	42.4%	1.2×10^{-31}	1.74

Note 1. Mean Correlation Values

Table 8-2
Bobbin to RPC Voltage Correlation
Sensitivity Analysis on Data Range

RPC Voltage Range	Correlation Coefficient (r^2) Linear-Linear Regression	RPC Volts[(1)] at 2 Bobbin Volts
0.1 to 3 volts[(2)]	43.3 %	1.51
0.2 to 2 volts	42.3 %	1.50
0.5 to 2 volts	30.8 %	1.46
0.5 to 1.5 volts	25.5 %	1.55
1.0 to 1.5 volts	7.0 %	1.46
1.0 to 2 volts	9.5 %	1.58

(1) Mean correlation values
(2) There is only data point between 2 to 3 volts

Table 8-3
Summary of Current Number and Target Number for Pulled Tube Intersections with Leakage

Voltage Range	Total No. of TSP Intersections		Current and Additional Target Number of Indications with Leakage				Comments
			¾" Tubing		7/8" Tubing		
	¾" Tubing	7/8" Tubing	Current No. Leakers	Additional Target No. Leakers	Current No. Leakers	Additional Target No. Leakers	
≤ 1.0	42	48	0	0	0	0	Negligible likelihood of leakage
> 1.0 – 2.0	16	25	1	0	0	0	Low (<20%) likelihood of leakage for 7/8" tubing
> 2.0 – 3.0	5	8	2	0	1	0	
> 3.0 – 4.0	3	8	1	1	0	2	
> 4.0 – 5.0	4	4	2	0	1	1	
> 5.0 – 6.0	1	5	1	1	0	2	
> 6.0 – 7.0	2	2	2	0	1	1	
> 7.0 – 8.0		1	0	2	1	1	
> 8.0 – 9.0	2	1	2	0	0	2	
> 9.0 – 10.0	3	1	3	0	0	2	
> 10.0 – 11.0	2		2	0	0	2	
> 11.0 – 12.0	3	3	3	0	0	2	
> 12.0 – 13.0		1	0	2	0	2	
> 13.0 – 14.0	1	2	1	1	1	1	
> 14.0 – 15.0			0	2	0	2	
> 15.0 – 16.0	2		2	0	0	2	
> 16.0 – 17.0	1	1	1	1	0	2	
> 17.0 – 18.0	1	4	1	1	1	1	
> 18.0 – 19.0		1	0	2	0	2	
> 19.0 – 20.0			0	2	0	2	
> 20.0	1	3	1	1	0	2	
> 30.0		4	0	2	1	1	
Total	**89**	**122**	**25**	**18**	**7**	**32**	

Figure 8-1
Bobbin to RPC Voltage Correlation for an Example Case
Bobbin Volts vs 80 mil Mid Range Pancake RPC Volts

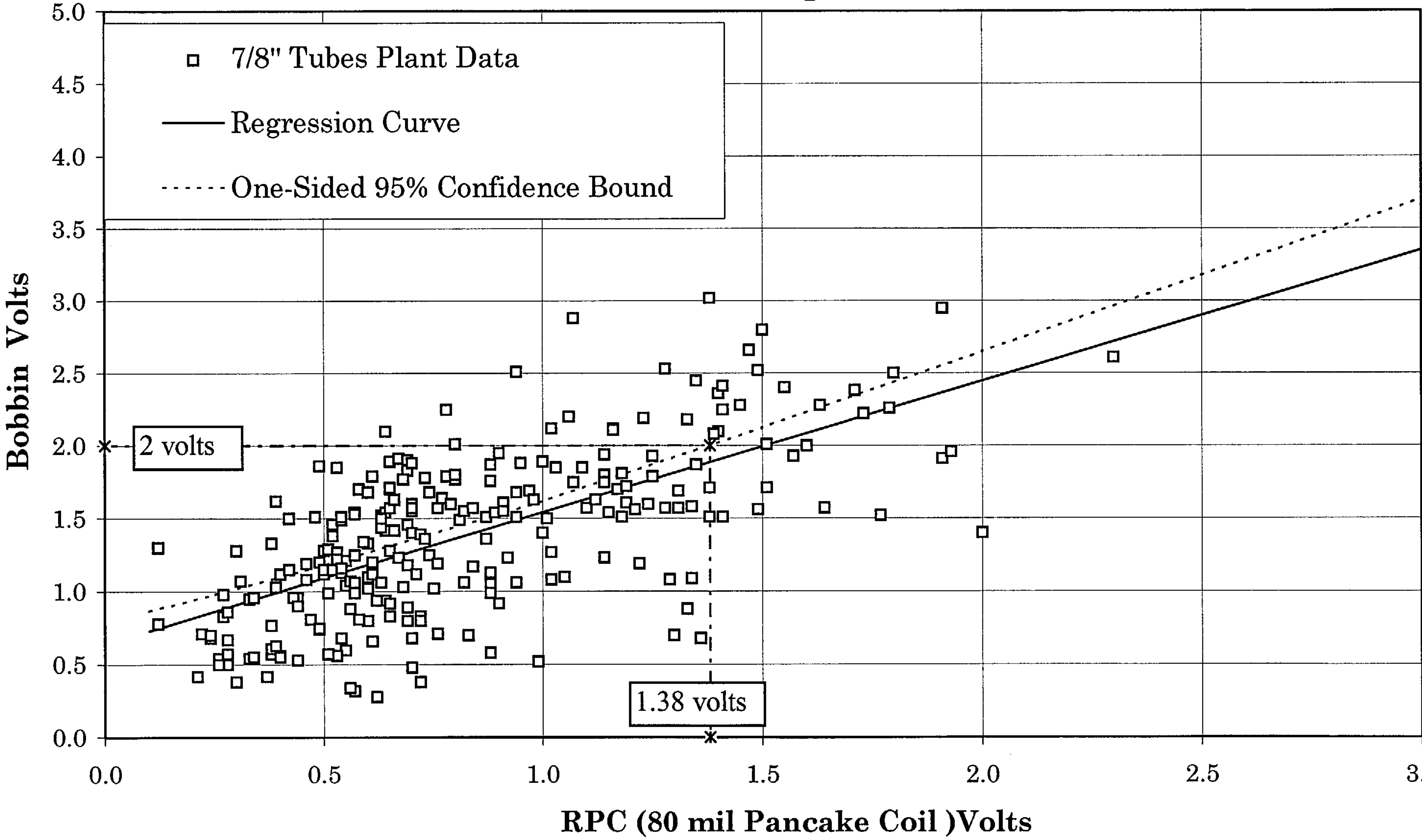


Figure 8-2
Bobbin to RPC Voltage Correlation for an Example Case
Scatter Plot of Residuals -- Linear Bobbin vs Linear RPC

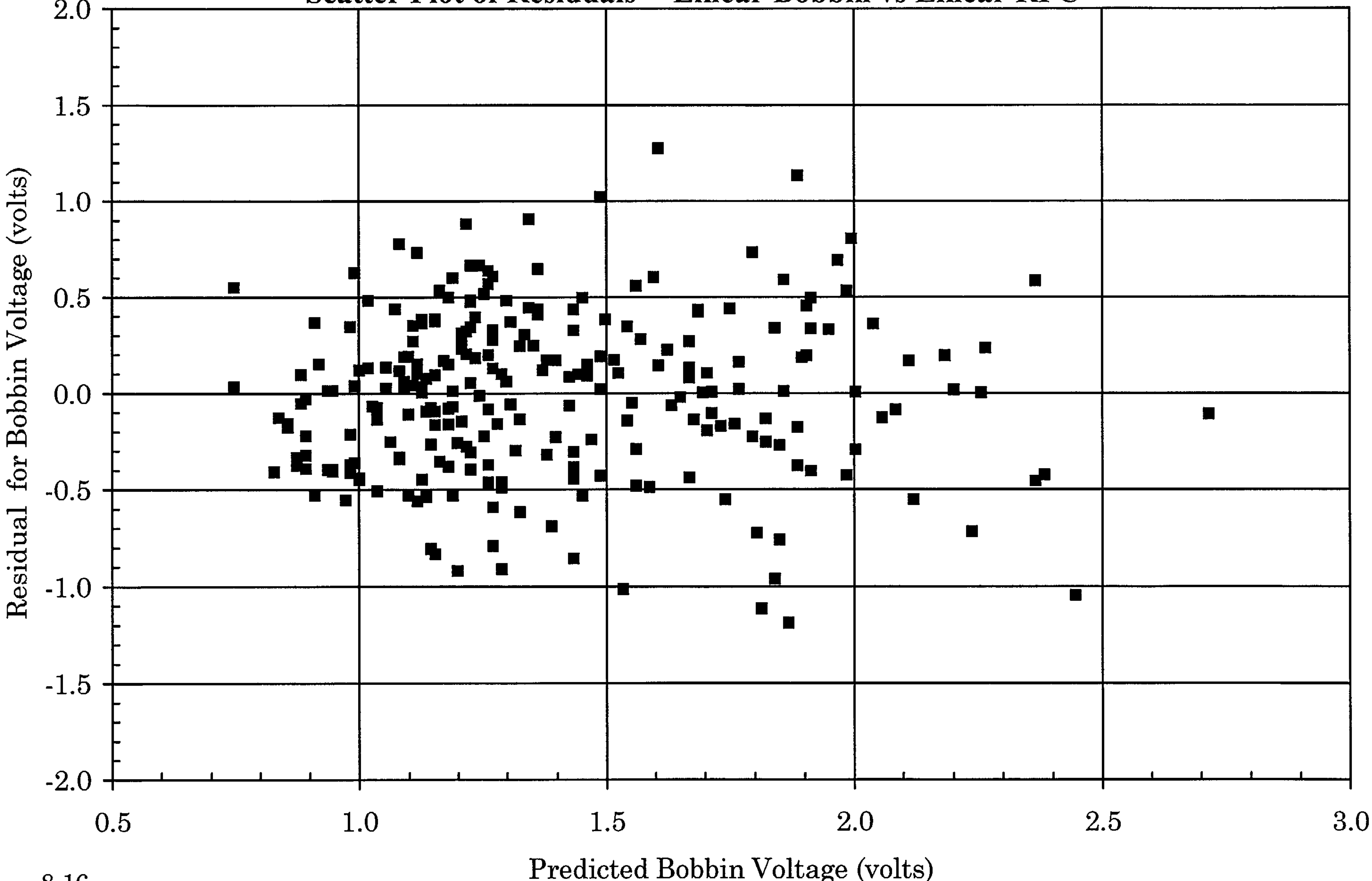
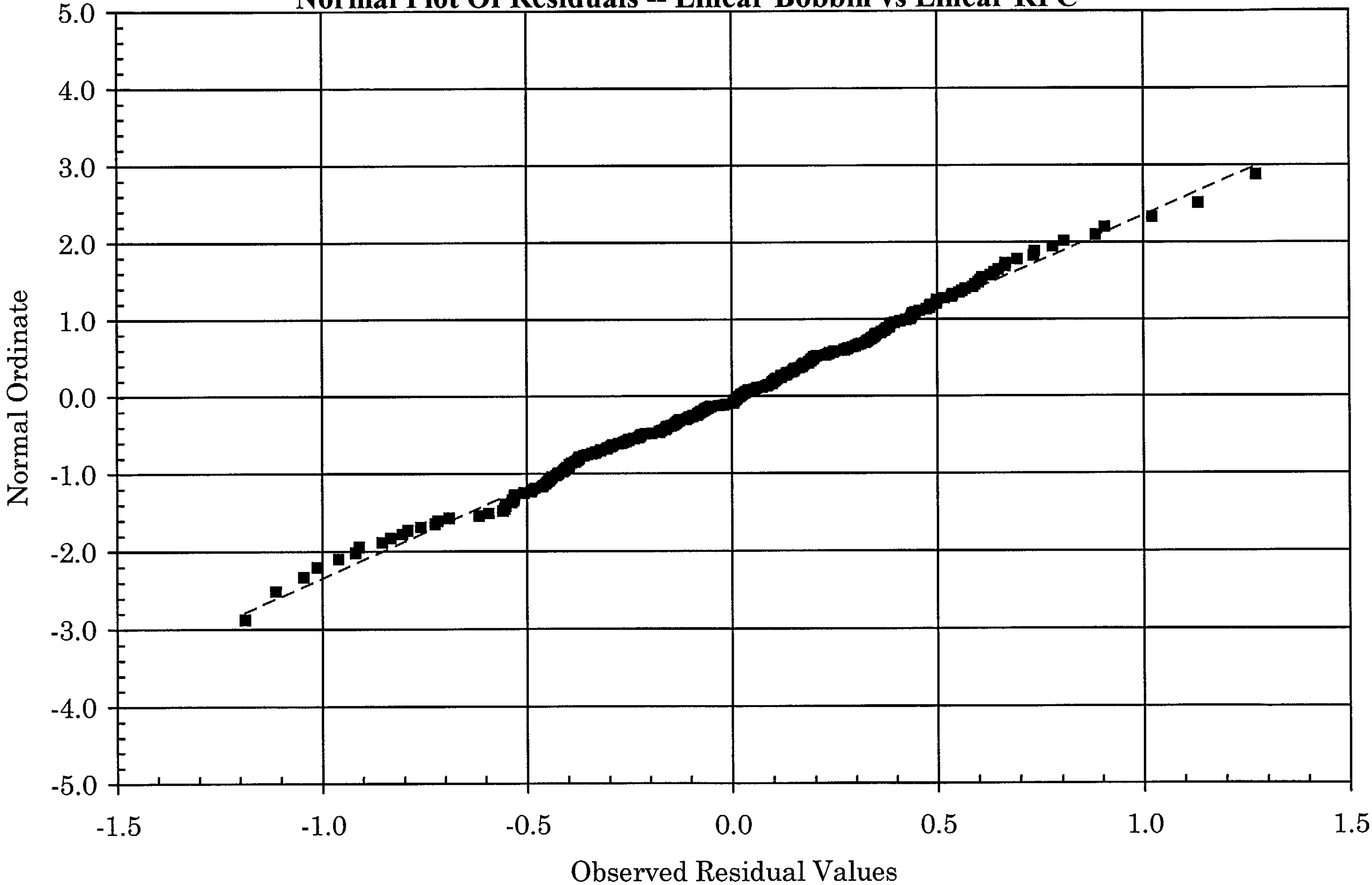


Figure 8-3
Bobbin to RPC Voltage Correlation for an Example Case
Normal Plot Of Residuals -- Linear Bobbin vs Linear RPC



Enclosure 2

STAFF COMMENTS ON INDUSTRY PROPOSED STEAM GENERATOR TUBE PULL PROGRAM

With industry proposed modifications

Generic Letter 95-05 Guidance	Industry Proposal	NRC Staff Comments	*Industry Modified Proposal*
Number of Frequency of Tube Pulls			
Two pulled tube specimens with an objective of retrieving as many intersections as is practical (a minimum of four intersections) should be obtained for each plant either during the plant SG inspection outage that implements the voltage-based repair criteria or during an inspection outage preceding initial application of these criteria.	Same as GL 95-05 with the following addition: However, if no pullable tube indications are found in this inspection that would satisfy the industry database target indications, the tube removal may be delayed (utility option) to the next planned inspection with the goal of obtaining indications satisfying the database target. The tube pulls may not be delayed more than one planned outage following implementation of the repair criteria	The staff finds this change acceptable.	*No Change*
Additional tube pulls with an objective of retrieving as many intersections as is practical (minimum of two intersections) should be obtained at the refueling outage following accumulation of 34 EFPMs of operation or at a maximum interval of three refueling outages, whichever is shorter, following the previous tube pull.	Same as GL 95-05 except for the timing the industry proposal is three operating cycles following the previous tube pull. In addition, the industry proposal would add: However, if no pullable tube indications are found in this inspection that would satisfy the industry database target indications, the tube removal may be delayed (utility option) to the	The staff finds this change acceptable	*No Change*

STAFF COMMENTS ON INDUSTRY PROPOSED STEAM GENERATOR TUBE PULL PROGRAM

With industry proposed modifications

Generic Letter 95-05 Guidance	Industry Proposal	NRC Staff Comments	*Industry Modified Proposal*
	next planned inspection with the goal of obtaining indications satisfying the database target. The tube pulls may not be delayed more than one planned outage following the required time for an additional pulled tube specimen. Consequently, the maximum interval between tube removals is four operating cycles to provide a periodic confirmation of crack morphology.		
Or participate in an industry sponsored tube pull program endorsed by the NRC that meets the objectives (1) to confirm the degradation mechanism for plants utilizing the GL for the first time, (2) to continue monitoring the ODSCC mechanism over time (3) to enhance the burst pressure, probability of leakage, and conditional leak rate correlations, and (4) to assess inspection capability.	Industry has proposed a tube pull program which is the subject of this letter.	N/A	
	If the above time requirements for a pulled tube specimen coincide with the plant's last scheduled outage before SG replacement, the requirement for a tube pull is waived.	The staff finds this change acceptable, except for the situation where the tube pull	*Industry agrees to the staff comments; change made in the*

Generic Letter 95-05 Guidance	Industry Proposal	NRC Staff Comments	*Industry Modified Proposal*
		specimens have not been obtained either during the plant SG inspection outage that implements the voltage-based repair criteria or during an inspection outage preceding initial application of these criteria.	*revised section 8 of update 3.*
	If indications with anticipated voltage levels substantially higher than the structural limit (for example, >10 volts) from the burst correlation are found in an inspection, the indication should be considered for removal and destructive examination if the test results are likely to determine whether or not condition monitoring or operational assessment results would satisfy acceptance limits.	The staff finds this change acceptable.	*No change*

STAFF COMMENTS ON INDUSTRY PROPOSED STEAM GENERATOR TUBE PULL PROGRAM
With industry proposed modifications

<u>**Generic Letter 95-05 Guidance**</u>	<u>**Industry Proposal**</u>	<u>**NRC Staff Comments**</u>	<u>***Industry Modified Proposal***</u>
<u>**Selection Criteria**</u>			
Should be an emphasis on removing tube intersections with large voltage indications.	The following would replace the current criteria: The primary emphasis for selecting an intersection for removal should be an indication that satisfies the target indication voltages of Table 8-3, "Summary of Current Number and Target Number for Pulled Tube Intersections with Leakage." If the target voltage range cannot be satisfied, the emphasis should be on intersections with large voltage indications.	The staff finds this change acceptable.	No change
Where possible, the removed tube intersections should cover a range of voltages, including intersections with no detectable degradation.	No Change	N/A	
As a minimum, selected intersections should ensure that the total data set include a representative number of intersections with RPC signatures indicative of a single dominant crack as compared to intersections with RPC signatures indicative of two or more dominant cracks about the circumference.	The following would replace the current criteria: For selection between indications of comparable voltage levels, the preference for removal should be intersections with RPC (or equivalent probe) signatures of a	The staff finds this change acceptable.	*No change*

Generic Letter 95-05 Guidance	Industry Proposal	NRC Staff Comments	*Industry Modified Proposal*
	single dominant crack as compared to intersections with RPC signatures indicative of two or more dominant cracks about the circumference.		
Examination and Testing			
Removed tube intersections should be subjected to leak and burst tests under simulated MSLB conditions to confirm that the failure mode is axial and to permit enhancement of the supporting data sets for the burst pressure and leakage correlators. The systems for future test should accommodate, the permit the measurement of, as high a leak rate as is practical, including leak rates that may be in the upper tail of the leak rate distribution for a given voltage. Leak rate data should be collected at temperature for the differential pressure loadings associated with the maximum postulated MSLB. When it is not practical to perform hot temperature leak tests, room temperature leak rate testing may be performed as an alternate. Burst testing may be performed at room temperature. The burst and leak rate correlations and/or data should be normalized to reflect the appropriate pressure and temperature assumptions for a postulated MSLB.	The following would be added: For small indications (<1.4 volt for ¾" tubing and 2.5 volt for 7/8" tubing), leak tests do not need to be performed if the field and post-pull NDE data clearly show crack depths not greater than 85%. These indications may be included in the probability of leakage correlation as non-leakers if the destructive examination results show maximum crack depths ≤ 95%.	The generic letter guidance should continue to be followed. NRC analysis shows that a 0.25 inch crack, 95% through wall, can pop through and leak under MSLB conditions. In addition, it is unclear whether the 85% number allows for eddy current uncertainties.	*Industry accepts staffs comment and will continue to follow GL 95-05 guidance.* *Changes made accordingly in the revised section 8 of update 13.*

STAFF COMMENTS ON INDUSTRY PROPOSED STEAM GENERATOR TUBE PULL PROGRAM

With industry proposed modifications

Generic Letter 95-05 Guidance	Industry Proposal	NRC Staff Comments	*Industry Modified Proposal*
Subsequent to burst testing, the intersections should be destructively examined to confirm that the degradation morphology is consistent with the assumed morphology for ODSCC at the tube-to-TSP intersections. The destructive examinations should include techniques such as metallography and scanning electron microscope (SEM) fractography as necessary to characterize the degradation morphology (e.g., axial ODSCC, circumferential ODSCC, IGA involvement, cellular IGA, and combinations thereof) and to characterize the largest crack networks with regard to their orientation, length, depth, and ligaments.* The purpose of these examinations is to verify that the degradation morphology is consistent with the assumptions made in Section 1.a of this attachment. This includes demonstrating that the dominant degradation mechanism affecting the tube burst and leakage properties is axially oriented, ODSCC.	The following would be added at the*. For uncorroded ligaments, the following information should be reported location within the elevation of the overall macrocrack angular orientation (approximate degrees) relative to the primary direction of the macrocrack; and size of the ligament such as uncorroded ligament area.	The staff finds this change acceptable.	No Change