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FARLEY UNIT-1

1999 VOLTAGE-BASED REPAIR CRITERIA 90 DAY REPORT

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1.0 INTRODUCTION

This report provides the Farley Unit-1 steam generator tube support plate (TSP) bobbin voltage data summary, together with postulated Steam Line Break (SLB) leak rate and tube burst probability analysis results. These results support continued implementation of the 2.0 volt voltage-based repair criteria for Cycle 16 as outlined in the NRC Generic Letter 95-05 (Reference 8.1). Information required by the generic letter is provided in this report including projections of bobbin voltage distributions, leak rates and burst probabilities for Cycle 16 operation. The methodology used in these evaluations is consistent with the NRC SER, Reference 8.2, Westinghouse generic methodology described in Reference 8.3, as well as the methodology reported in the prior voltage-based repair criteria reports for Farley Unit-1 (References 8.4 and 8.5).

Eddy current and repair data for TSP indications are provided in Section 3. No tubes were deplugged during the EOC-15 outage. The actual EOC-15 voltage distributions as well as leak rates and tube burst probabilities calculated for these distributions are compared with the projections for the EOC-15 conditions performed using the EOC-14 data. Leak rates and burst probabilities for the projected EOC-16 voltage distributions are reported in Section 7 and compared with allowable limits.

2.0 SUMMARY AND CONCLUSIONS

SLB leak rate and tube burst probability analyses were performed for all three steam generators (SGs) based on their actual measured end of Cycle 15 (EOC-15) voltage distributions and the results compared with the projections performed at the beginning of Cycle 15 (BOC-15). The total number of indications found at TSPs in each SG during the current inspection and the actual measured peak voltages are less than those projected at the BOC-15 per the Generic Letter 95-05 requirements using a constant POD of 0.6. With the alternate EOC-15 projections based on the voltage-dependent POPCD, the total number of indications is overestimated for SG B, but slightly underestimated for SGs A and C (by about 2% and 10%, respectively); however, the more important EOC-15 peak voltages are overpredicted for all three SGs with POPCD. Leakage rates and tube burst probabilities calculated using the actual measured voltages are well below those projected with both a constant POD of 0.6 as well as the voltage-dependent POPCD. SG-C was predicted to be the limiting SG at EOC-15 and was also found limiting based on the actual measured EOC-15 voltage data.

For the actual EOC-15 bobbin voltage distribution, the largest SLB leak rate is calculated for SG-C, and its magnitude is 5.3 gpm. Although a voltage dependent leak rate correlation can now be applied for 7/8" tubes, leak rates for all SGs based on the actual EOC-15 voltages were obtained assuming leak rate is independent of bobbin voltage so that they can be compared with the projections performed at the BOC-15 which used voltage independent leak rates. Also, the same leak and burst database applied for EOC-15 projections was used (documented in Reference 8.6), which did not include the 1996 Farley-2, 1997 Farley-1 data and 1996 W-2 data since they do not significantly impact the leak rate and burst pressure correlations and there was no requirement to incorporate them into the database until the general database update performed in 1998. The limiting leak rate thus calculated using the EOC-15 measured voltages (5.3 gpm for SG-C) is substantially lower than the current allowable SLB leakage limit of 23.8 gpm. A more realistic limiting EOC-15 leak rate obtained using the latest leak rate correlation (based the NRC approved EPRI database presented in Reference 8.7) available for 7/8" tubes (3.8 gpm) shows even a greater margin. All leak rate values quoted are equivalent volumetric rates at room temperature. The corresponding conditional tube burst probability based on the actual EOC-15 voltage data for SG-C is 2.1×10^{-3} (2.3×10^{-3} based on the Reference 8.7 leak and burst database for 7/8" tubes), and it is well within the NRC reporting guideline of 10^{-2}.

SLB leak rate and tube burst probability were also projected to the EOC-16 conditions for all 3 SGs. SG-C is again predicted to be the limiting SG since it has the highest total number of indications as well as the number of indications over 1 and 2 volts returned to service for Cycle 16 operation. EOC-16 leak rate projections were performed using the leak rate versus bobbin voltage correlation for 7/8" tubes presented in Reference 8.7. A leak rate correlation can now be applied to 7/8" tubes based on the p-value for the slope of the leak rate correlation on a one-sided basis meeting the Generic Letter 95-05 requirement. Cycle 15 growth data were used in the EOC-16 projection analysis. The data show a slight dependency on the beginning of cycle voltage; therefore, EOC-16 leak rate and tube burst probability were calculated using the method recommended in Reference 8.7 to account for voltage-dependent growth, in addition to calculations using the conventional method (Reference 8.3) which assumes growth rate is independent of the BOC voltage. With the NRC mandated constant POD of 0.6, the EOC-16 SLB leak rate for SG-C is projected to be 8.2 gpm (room temperature) with the voltage-dependent growth method and 7.7 gpm based on the original method. Both these leak rate values are well within the current licensed limit of 23.8 gpm (room temperature). The corresponding EOC-16 tube burst probability values calculated for SG-C are 5.6×10^{-3} with the voltage-dependent growth and 3.1×10^{-3} with the conventional method. Again, both these burst probability estimates are below the NRC reporting guideline of 10^{-2}. Thus, the GL 95-05 requirements for returning the plant to Cycle 16 service and for full cycle of operation are met.

A total of 3502 indications were found in the EOC-15 inspection, of which 107 are over 2 volts. Of these 3502 indications, 469 indications which includes all 107 indications over 2 volts were inspected with a rotating pancake coil (RPC), and 436 were confirmed as flaws. The largest number of bobbin indications, 1362 indications, were found in SG-C; 169 were inspected by RPC, and 158 were confirmed as flaws. The above indication count data include 210 outside diameter stress corrosion cracking (ODSCC) indications detected with a +Point probe during the expanded RPC probe inspection for circumferential cracks in dented TSP intersections. The bobbin voltage for such ODSCC indications were obtained by converting the voltage recorded with a 80 mil RPC using a correlation established earlier between 80 mil pancake and bobbin coil voltages for Farley-1 SG indications.

The largest indications found in SGs A, B, and C this inspection were 6.65, 7.17 and 10.15 volts, respectively. These indications were in situ leak tested up to SLB conditions and no leakage was found for any of the indications. Since one or more of the indications would be expected to leak under free span conditions, the in situ tests demonstrate the packed crevice restraint on leakage under the expected "locked" TSP conditions.

Six indications were initially reported as circumferential OD indications during the RPC inspection; four of them were identified as ODSCC circumferential indications, and they were found in dented intersections. The other two indications were confirmed as cellular ODSCC patches based on a UT examination. Since circumferential indications (distinct from cellular corrosion) were identified at dented intersections (2 found initially) in the > 5 volt dent inspection program, the +Point inspection was expanded to the known dented locations between 3 to 5 volts; two more circumferential indications were detected in SG-B in the expanded inspection. All four circ indications had modest circumferential extent ($\leq$ 110 °), and none were found to challenge structural or leakage integrity. All tubes identified with circumferential indications were repaired. Two indications were found to potentially extend slightly ($\leq$ 0.08") outside the TSP by detailed depth profiling with the +Point coil. This short extension outside the TSP is less than the uncertainty in locating the crack tip such that the indications could be entirely within the TSP. As circumferential indications and axial indications extending outside TSP were identified, they must be reported to the NRC per the GL 95-05 requirements.

3.0 EOC-15 INSPECTION RESULTS AND VOLTAGE GROWTH RATES

3.1 EOC-15 Inspection Results

In accordance with the guidance for application of the voltage-based repair criteria provided in Generic Letter 95-05 (Reference 8.1), the EOC-15 inspection of the Farley Unit-1 SGs consisted of a complete 100% bobbin probe full length examination of all TSP intersections in the tube bundles of all three SGs. A 0.720 inch diameter probe was used for all hot and cold leg TSPs where voltage-based repair criteria were applied. Subsequently, RPC examination was performed for all bobbin indications with amplitudes greater than 2 volts in all three SGs. One hundred and seven indications were found above 2 volts in all SGs combined; they were all inspected with RPC, and all but 6 of them were confirmed as flaws and removed from service. No volumetric or copper-type signals were identified by RPC inspection at TSP intersections. The largest indication in each SG (6.65, 7.17 and 10.15 volts respectively in SGs A, B and C) were in-situ leak tested and none of them leaked.

An augmented RPC inspection was performed consistent with the Generic Letter 95-05 requirements. All dented intersections with a bobbin voltage greater than 5 volts were inspected with a RPC probe. Six indications were initially reported as circumferential OD indications at dented intersections and four of them were identified as ODSCC circ indications. The other two indications were confirmed as cellular ODSCC patches based on a UT examination. Since circumferential indications (distinct from cellular corrosion) were identified at dented intersections (2 found initially) in the > 5 volt dent inspection program, the +Point inspection was expanded to the known dented locations between 3 to 5 volts; two more circumferential indications were detected in SG-B in the expanded inspection. All tubes identified with circumferential indications were repaired. Additional details on these circumferential indications are presented in the next section.

During the expanded RPC inspection for circumferential cracks in dented TSP intersections, an additional 210 ODSCC indications were detected by the +Point probe. The bobbin voltage for those ODSCC indications were obtained by converting the RPC voltage from a 80 mil coil using a correlation established earlier between 80 mil pancake coil and bobbin coil voltages for 7/8" tubes, which is shown below.

$$V_b = 0.78 + 0.81 \times V_{rpc} + 0.06 \times V_{rpc}^2$$

where V_b represents the bobbin voltage corresponding to the 80 mil pancake voltage V_{rpc}.

The largest bobbin detected indications in SG-A (R2C86, 6.65 volts) and SG-B (R2C75, 7.17 volts) were found to potentially extend outside the TSP. Although not found outside the TSP in the conventional field analysis, detailed depth profiling of the +Point data indicated potential extensions outside the TSP of 0.05 inch for R2C75 and 0.08 inch for R2C86. No coil lead-in or lead-out corrections were applied to the +Point data and the crack length may be overestimated. UT inspection results indicated a length outside the TSP of 0.06 inch for R2C75 and 0.13 inch for R2C86.

A summary of bobbin voltage distributions for all steam generators is shown on Table 3-1; the 210 ODSCC indications detected by the +Point probe are included in these distributions (at an equivalent bobbin voltage calculated using the 80 mil RPC voltage for those indications in the above correlation between the bobbin and RPC voltages). Table 3-1 tabulates the number of TSP ODSCC indications reported, the number of these indications that were RPC inspected (either with a 80 mil pancake or +Point coil), the number of RPC confirmed indications, and the number of indications removed from service due to tube repairs. The indications that remain active for Cycle 16 operation is the difference between the observed and the ones removed from service. As required by GL 95-05, the bobbin voltage distributions for the BOC-16 indication population exclusive of EOC-15 RPC NDD indications (i.e., indications that were either RPC confirmed or not RPC inspected in the EOC-15 inspection) are also provided. No tubes were deplugged in the current inspection.

Overall, the combined data for the Farley Unit-1 steam generators show the following:

- A total of 3502 ODSCC indications were identified at the TSP intersections during the inspection including the 210 indications that were detected by the +Point probe during the augmented RPC inspection.

- Of the 3502 indications, 1399 were above 1 volt and 107 exceeded 2 volts.

- A total of 469 indications (including all 107 over 2 volts) were RPC inspected and 436 were confirmed as flaws.

- A total of 339 indications were removed from service due to tube repairs; of these 101 indications exceeding 2 volts were repaired due to ODSCC at TSPs. The rest of the indications are in tubes plugged for degradation mechanisms other than ODSCC at TSPs.

A review of Table 3-1 indicates that more indications (a quantity of 1219, with 513 indications above 1.0 volt and 1 RPC NDD indication over 2 volts) were returned to service in SG-C, than in the other 2 SGs. Clearly, SG-C will be the limiting SG at EOC-16. Figure 3-1 shows the actual bobbin voltage distribution for tubes that were in service during Cycle 15, as determined from the EOC-15 EC inspection. Figure 3-2 shows the distribution of the EOC-15 bobbin indications that were repaired and taken out of service, and Figure 3-3 shows the bobbin voltage distribution of indications returned to service for BOC-16.

The distribution of EOC-15 indications as a function of support plate elevation is summarized in Table 3-2 and illustrated on Figure 3-4. The 210 indications detected with the +Point probe are not included in Table 3-2 and Figure 3-4 because their growth rate cannot be estimated as their BOC-15 voltage data are not available. The data shown confirm the predisposition of ODSCC to occur in the first few hot leg TSPs (2678 of the 3292 PIs, or about 81%, occurred in the first four hot leg TSPs), although the mechanism does extend to higher TSPs. Only eighty-two bobbin indications (or about 2.5%) were reported on the cold-leg side. This distribution has remained unchanged during the last several inspections, and it shows the predominant temperature dependence of ODSCC at Farley Unit-1, similar to that observed at other plants.

3.2 Circumferential Indications at Tube Support Plates

The distribution of indications at TSP intersections reported include 3 locations showing circumferential ODSCC +Point responses in each of SG A and SG B; there were no TSP circumferential indications in SG C. Additional details on these indications are presented below.

3.2.1 GL 95-05 Required +Point Examinations

In SG A, one of the circumferential indications was associated with a 5.8V dent at 5H (R12C2); this location was examined with +Point as part of the ≥ 5V dent program required by the voltage-based repair criteria. R35C17 in SG B exhibited a 4.89V dent signal as well as a 2.15V bobbin indication in the TSP; +Point examination, as required by the repair criteria, also identified a circumferential indication inside the TSP but not intersecting the axial indication (i.e., not a mixed mode indication) that produced the bobbin indication.

Two 1H locations (R8C2 and R23C79) in SG-A were +Point-examined in conjunction with bobbin indications reported at or near the TSP. For R8C2 the bobbin indication inside the TSP exceeded 2V, requiring rotating probe inspection per the voltage-based repair criteria; for R23C79, a sleeved tube, a bobbin indication (NQI) just outside the TSP necessitated +Point examination even though a 1.98V bobbin indication inside the

TSP did not require +Point inspection. In these cases, a UT examination found that the degradation present was more appropriately classified as cellular ODSCC, as reflected by the short, multiple axial and oblique orientation of the prominent UT indications. Based on the UT characterization of the locations with circumferential indications, which was consistent with patterns observed in other industry tube pull experience, e.g., Trojan in 1991, the presence of circumferentially oriented ODSCC indications at non-dented TSP intersections is attributed to cellular ODSCC patches. This characterization is consistent with cases in which significant bobbin indications are observed and may apply where dents could obscure the visibility of relatively minor degradation.

3.2.2 EPRI Guidelines Expansion

Since 1 of the 2 circumferential indications (distinct from cellular corrosion) identified in the initial inspection occurred in a < 5V dent, the +Point inspection program was expanded to the known dented locations (3 to 5 volts). A critical area for the inspection was defined as hot leg dents up to the highest TSP with circumferential indications. The next highest TSP defines the buffer zone. In SGs A and B where circumferential indications were found, this inspection included 100% of the dents up to TSP 5 and 20% of the hot leg dents up to TSP 7; a 20% sample of the 3-5 volt hot leg dents was examined in SG C. This program resulted in the identification of circumferential indications at 2 more TSP locations in SG B, one each on R21C19-2H (3.35 volt dent) and R45C59-5H (4.35 volt dent); no additional circumferential indications were detected in SG A nor were any detected in SG C.

3.2.3 Evaluation of TSP Circumferential Indications

All four indications identified as ODSCC circumferential indications were found in dented intersections. These indications had modest circumferential extent ($\leq 110°$), and such indications do not challenge structural or leakage integrity. All tubes identified with circumferential indications were repaired.

3.3 Voltage Growth Rates

The EOC-15 field bobbin voltages were reevaluated to obtain more reliable growth data for Cycle 15. The Cycle 15 bobbin voltage growth data for all 3 SGs are shown in Table 3-3 in the form of cumulative probability distribution functions (CPDF), and the same data is also presented in a graphical form on Figure 3-5. Growth rates for the last two cycles are plotted in Figure 3-6, and the data show that growth rates during Cycle 15 are more limiting for the last two operating periods. The NRC guidelines require that the more conservative growth distribution for the last two operating periods be applied for projecting the next cycle distributions. Therefore, Cycle 15 growth data will be applied to obtain EOC-16 projections.

Table 3-4 shows average voltage growth rates for all three Farley Unit-1 SGs during Cycle 15 as well as the growth data for indication population with BOC-15 voltage below and above 0.75 volt. The average voltage growth rate for the three SGs vary from 12.3% (SG-C) to 17.9% (SG-A) with an overall average of 14.5%, on an effective full power year (EFPY) basis. According to the Westinghouse analysis methodology presented in Reference 8.3, the larger of the composite growth rate for all SGs and the SG-specific growth rate should be used in projecting SLB leak rate and tube burst probability for individual SGs. The Cycle 15 growth rates for SGs B and C are below the composite growth rate and, therefore, the composite growth rate is applied to those two SGs to provide a conservative basis for predicting the EOC-16 conditions. Predictions for SG-A are obtained using its own growth rate since it is higher than the composite rate. Both SGs B and C have one indication with Cycle 15 growth higher than the largest growth in SG-A. Since the largest growth for a cycle can occur randomly in any of the SGs, the largest growth values for SGs B and C were added to the growth distribution used for the leak and burst analysis for SG-A.

The average growth for indications with a BOC bobbin voltage above 0.75 volt is 13.8% per EFPY and for indications below 0.75 volt it is 16.3% per EFPY. A slightly smaller percentage growth observed for BOC volts above 0.75 (relative to BOC volts below 0.75) is consistent with the data for the past inspections for Farley Unit-1, although the magnitude of the above growth rate difference is not significant. Table 3-5 provides a comparison of average growth data for the last 9 operating cycles. The data generally show a steady reduction in the average growth rates, except for the last two cycles which show modestly higher growth rates.

In the past, SGs in some plants have experienced growth rates that are dependent on the BOC voltage. To determine if the Cycle 15 growth data for Farley Unit-1 exhibited a dependency on BOC voltage, Cycle 15 growth data was plotted against the BOC-15 voltage, and the resulting plot is shown in Figure 3-7. The data indicate that the ODSCC indication growth is beginning to show dependency on the beginning of cycle voltage, as a greater fraction of indications over 1.5 volts show growth over 1 volt than indications under 1.5 volts. Therefore, the EOC-16 leak rate and burst probability projections for the limiting SG (SG-C) are also calculated taking into account the growth dependency on the BOC voltage.

Table 3-6 lists the top 30 indications from the standpoint of growth during Cycle 15 and all indications were confirmed by RPC Inspection. Twelve of these 30 indications are new for Cycle 15. None of these 12 new indications with over 1 volt growth occurred in tubes for which alternate probe wear criteria described in Reference 8.8 were applied during the EOC-14 inspection. Therefore, the alternate probe wear criteria applied during the EOC-14 inspection are not the cause for non-detection of these indications at EOC-14. Eight of these 12 new indications had BOC-15 bobbin voltages between 1 to 2 volts. These voltages are towards the high side for expected undetected indications although supporting a high POD above about 2 volts.

3.4 Probe Wear Criteria

The alternate probe wear criteria discussed in Reference 8.8 were applied during the EOC-15 inspection. When a probe does not pass the 15% wear limit, this alternate criteria require that all tubes with indications above 75% of the repair limit since the last successful probe wear check be reinspected with a good probe. Accordingly, all tubes containing one or more indications with a worn probe voltage above 1.5 volts were inspected with a new probe. An evaluation of worn probe and new probe data is presented in the following paragraphs.

In accordance with the guidance provided in Reference 8.8, voltages measured with a worn probe and a new probe at the same location were analyzed to ensure that the voltages measured with worn probes are within 75% of the new probe voltages. No new large indications were detected with new probes; thus, worn probes did not miss significant indications. Figure 3-8 shows plots of the worn probe voltages plotted against the new probe voltages for all three SGs. The data in Figure 3-8 show a consistent relationship between the two voltages, with the worn probe voltage generally higher than the new probe voltage. The composite data from all three SGs are plotted in Figure 3-9. Also shown in Figure 3-9 as a solid line is a linear regression for the data, dashed lines representing tolerance limits that bound 90% of the population at 95% confidence, and chained lines representing ±25% band for the new probe voltages. The mean regression line has about 46° slope indicating that, on the average, worn probe voltages were slightly higher than the new probe voltages. The dotted horizontal line at 1.5 worn probe volts demarcates indications requiring retest from those that do not. The shaded area at the bottom shows the region where a defective tube may be left in service because of probe wear. In the Farley Unit-1 EOC-15 inspection, there are no occurrences for which a worn probe was less than 1.5 volts and the new probe voltage exceeded the repair limit, i.e., no defective tubes were missed due to probe wear considerations.

Overall, it is concluded that the criteria to retest tubes with worn probe voltages above 75% of the repair limit is adequate. The alternate probe wear criteria used in the EOC-15 inspection is consistent with the NRC guidance provided in Reference 8.8.

3.5 Probability of Prior Cycle Detection (POPCD)

The inspection results at EOC-15 permit an evaluation of the probability of detection at the prior EOC-14 inspection. For voltage-based repair criteria applications, the important indications are those that could significantly contribute to EOC leakage or burst probability. These significant indications can be expected to be detected by bobbin and confirmed by RPC inspection. Thus, the population of interest for POD assessments is the EOC RPC confirmed indications that were detected or not detected at the prior inspection. The probability of prior cycle detection (POPCD) for the EOC-14 inspection can then be defined as follows.

$$\text{POPCD (EOC-14)} = \frac{\begin{array}{l}\text{EOC-14 cycle reported bobbin} \\ \text{indications confirmed by RPC} \\ \text{in EOC-15 inspection}\end{array} + \begin{array}{l}\text{Bobbin indications} \\ \text{confirmed and repaired in} \\ \text{EOC-14 inspection}\end{array}}{\{\text{Numerator}\} + \begin{array}{l}\text{New indications RPC} \\ \text{confirmed in EOC-15} \\ \text{inspection}\end{array}}$$

POPCD is evaluated at the 1997 EOC-14 voltage values (from 1998 reevaluation for growth rate) since it is an EOC-14 POPCD assessment. The indications at EOC-14 that were RPC confirmed and repaired are included as it can be expected that these indications would also have been detected and confirmed at EOC-15. It is also appropriate to include the plugged tubes for voltage-based repair criteria applications since POD adjustments to define the BOC distribution are applied prior to reduction of the EOC indication distribution for plugged tubes.

It should be noted that the above POPCD definition includes all new EOC-15 indications not reported in the EOC-14 inspection. The new indications include EOC-14 indications present at detectable levels but not reported, indications present at EOC-14 below detectable levels and indications that initiated during Cycle 15. Thus, this definition, by including newly initiated indications, differs from the traditional POD definition. Since the newly initiated indications are appropriate for voltage-based repair criteria applications, POPCD is an acceptable definition and eliminates the need to adjust the traditional POD for new indications.

The above definition for POPCD would be entirely appropriate if all EOC-14 indications were RPC inspected. Since only a fraction of bobbin indications are generally RPC inspected, POPCD could be distorted by using only the RPC inspected indications. Thus, a more appropriate POPCD estimate can be made by assuming that all bobbin indications not RPC inspected would have been RPC confirmed. This definition is applied only for the 1998 EOC-15 indications not RPC inspected since inclusion of the EOC-14 repaired indications could increase POPCD by including indications on a tube plugged for non-ODSCC causes which could be RPC NDD indications. In addition, the objective of using RPC confirmation for POPCD is to distinguish detection of an indication at EOC_{n-1} that could contribute to burst at EOC_n so that the emphasis is on EOC_n RPC confirmation. This POPCD can be obtained by replacing the EOC-15 RPC confirmed by RPC confirmed plus not RPC inspected in the above definition of POPCD. For this report, both POPCD definitions are evaluated for Farley Unit-1.

The POPCD evaluation for the 1997 EOC-14 inspection data is summarized in Table 3-7 and illustrated on Figure 3-10. Data for both RPC confirmed only indications and RPC confirmed plus not RPC inspected indications are shown in Table 3-7 and Figure 3-10. Also shown in Figure 3-10 is a generic POPCD distribution developed by analyses of 18 inspections in 10 plants and presented in Table 7-4 of Reference 8.7. It is seen from Figure 3-10 that the predicted POPCD values for Farley Unit-1 are equal to or better than the generic POPCD except for 1.5 to 2 volts range. An explanation for relatively lower POD values between 1.5 to 2 volts is provided in the next paragraph. POPCD for Farley Unit-1 remains at or above 0.8 beyond 0.6 volt and approaches unity above 2 volts.

A few indications had been assigned large voltages at both the current and prior inspections. The large voltage assignments are based upon the NDE analyst guidance to assign a conservative voltage when in doubt on the actual flaw voltage indicated. Three of these indications were reanalyzed to assign a more accurate flaw voltage for use in the POPCD evaluation. Figures 3-11 to 3-13 show the field and reevaluated EOC-14 voltages for these 3 indications. The reanalyzed voltages use the 200 kHz data to help identify the flaw (EOC-14 voltage for R40C59 1H indication in SG-C reduced from 2.45 to 1.67 volts, see Figure 3-11) or eliminate part of the TSP response when there is not a well defined flaw signal (R2C84 1H in SG-A voltage reduced from 3.83 to 1.21 volts and 2H voltage reduced from 2.69 to 0.79 volts, see Figures 3-12 and 3-13). The reanalyzed voltages for these 3 indications were included in the POPCD evaluations only, and the EOC-16 SLB leak rate and burst probability analyses utilized the conservative voltages assigned during the inspection. Signal distortions, such as for these indications, is a frequent occurrence in the Farley Unit-1 SGs, and the conservative voltages tend to imply lower POPCD above about 1 volt. It is believed that the lower Farley POPCD shown in Figure 3-10 in the voltage range 1 to 2 volts is strongly influenced by the conservative voltage assignments.

In summary, the Farley Unit-1 EOC-14 POPCD supports a voltage dependent POD higher than the NRC mandated POD value of 0.6 above about 0.4 volt and approaching unity at above 2 volts. It is concluded that the POD applied for leak and burst projections needs to be upgraded from the constant POD value of 0.6 to a voltage dependent POD.

3.6 Assessment of RPC Confirmation Rates

This section tracks the 1997 EOC-14 indications left in service at BOC-15 relative to RPC inspection results in 1998 at EOC-15. The composite results for all SGs are given in Table 3-8. For the 1997 bobbin indications left in service, the indications are tracked relative to 1997 RPC confirmed, 1997 RPC NDD, 1997 bobbin indications not RPC inspected and 1997 bobbin indications with no indication found in 1998. Also included are new 1998 indications. The table shows, for each category of indications, the number of indications RPC inspected and RPC confirmed in 1998 as well as the percentage of RPC confirmed indications.

Twenty-three of the 131 RPC NDD indications left in service at BOC-15 were RPC tested during the EOC-15 inspection, and 9 were confirmed. Therefore, the confirmation rate for 1997 RPC NDD indications is 39%. This result is consistent with a similar evaluation carried out after the last (EOC-14) outage that yielded 46% confirmation rate for prior cycle RPC NDD indications. The NRC Generic Letter 95-05 (Reference 8.1), upon NRC approval, allows for consideration of only a fraction of RPC NDD indications from a current inspection in establishing the BOC voltage distribution for the next cycle. A fractional value appropriate for GL 95-05 applications is the largest RPC confirmation rate for prior cycle RPC NDD indications found during the last two outages. Thus, based on the data available it would be justifiable to consider 46% of RPC NDD indications for projecting EOC voltage distributions for Farley Unit-1. However, since NRC approval has not been obtained, leak and burst analyses presented in this report are based on 100% of RPC NDD indications.

3.7 NDE Uncertainties

The NDE uncertainties applied for the EOC-15 voltage projections in this report are those given in GL 95-05 and used in the prior Farley Unit-1 reports (References 8.4 and 8.5). The probe wear uncertainty has a standard deviation of 7.0 % about a mean of zero and has a cutoff at 15% based on implementation of the probe wear standard. The analyst variability uncertainty has a standard deviation of 9.3% about a mean of zero with no cutoff. These NDE uncertainty distributions are included in the Monte Carlo analyses used to project the EOC-15 voltage distributions.

Table 3-1 (Sheet 1 of 2)
Farley Unit 1 November 98 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 15

Voltage Bin	Steam Generator A						Steam Generator B					
	In-Service During Cycle 15				RTS for Cycle 16		In-Service During Cycle 15				RTS for Cycle 16	
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.1	0	0	0	0	0	0	1	1	1	0	1	1
0.2	3	3	3	0	3	3	24	23	23	0	24	24
0.3	10	9	9	4	6	6	31	23	23	5	26	26
0.4	23	3	2	1	22	21	70	22	22	1	69	69
0.5	62	6	6	2	60	60	92	14	14	3	89	89
0.6	77	1	1	0	77	77	115	9	9	4	111	111
0.7	100	3	3	4	96	96	114	9	9	5	109	109
0.8	83	1	1	7	76	76	123	16	16	5	118	118
0.9	110	1	1	9	101	101	113	16	15	7	106	105
1	91	0	0	4	87	87	99	17	14	6	93	90
1.1	75	2	0	4	71	70	88	11	8	4	84	81
1.2	74	2	1	3	71	70	56	9	7	8	48	46
1.3	72	0	0	6	66	66	47	4	3	3	44	43
1.4	56	3	3	5	51	51	20	2	1	3	17	16
1.5	33	0	0	1	32	32	35	2	2	5	30	30
1.6	42	0	0	2	40	40	15	3	1	4	11	10
1.7	24	1	1	3	21	21	11	0	0	1	10	10
1.8	23	1	1	2	21	21	12	5	4	0	12	11
1.9	17	0	0	2	15	15	4	1	1	0	4	4
2	18	3	2	3	15	15	4	1	1	1	2	2
2.1	5	5	4	5	0	0	1	1	1	1	1	1
2.2	13	13	13	13	0	0	10	10	10	10	0	0
2.3	4	4	4	4	0	0	3	3	3	3	0	0
2.4	4	4	3	3	1	0	2	2	2	2	0	0
2.5	1	1	1	1	0	0	0	0	0	0	0	0
2.6	3	3	3	3	0	0	1	1	1	1	0	0
2.7	4	4	4	4	0	0	2	2	1	1	1	0
2.8	1	1	1	1	0	0	0	0	0	0	0	0
2.9	1	1	1	1	0	0	1	1	1	1	0	0
3	3	3	3	3	0	0	2	2	2	2	0	0
3.1	2	2	2	2	0	0	0	0	0	0	0	0
3.3	1	1	1	1	0	0	1	1	1	1	0	0
3.4	1	1	1	1	0	0	0	0	0	0	0	0
3.5	0	0	0	0	0	0	0	0	0	0	0	0
3.7	0	0	0	0	0	0	1	1	1	1	0	0
4.1	1	1	1	1	0	0	1	1	1	1	0	0
4.3	0	0	0	0	0	0	0	0	0	0	0	0
4.6	1	1	1	1	0	0	0	0	0	0	0	0
4.9	0	0	0	0	0	0	1	1	1	1	0	0
6.7	1	1	1	1	0	0	0	0	0	0	0	0
7.2	0	0	0	0	0	0	1	1	1	[illegible]	0	0
10.15	0	0	0	0	0	0	0	0	0	0	0	0
Total	1039	85	78	107	932	928	1101	215	200	91	1010	996
> 1 volt	480	58	52	76	404	401	319	65	54	55	264	254
> 2 volts	46	46	44	45	1	0	27	27	26	26	2	1

Table 3-1 (Sheet 2 of 2)
Farley Unit 1 November 98 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 15

Voltage Bin	Steam Generator C						Composite of All SGs					
	In-Service During Cycle 15				RTS for Cycle 16		In-Service During Cycle 15				RTS for Cycle 16	
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.1	0	0	0	0	0	0	1	1	1	0	1	1
0.2	22	22	21	1	20	20	49	48	47	1	48	47
0.3	26	20	20	2	24	24	67	52	52	11	56	56
0.4	33	17	17	0	33	33	126	42	41	2	124	123
0.5	57	11	11	1	56	56	211	31	31	6	205	205
0.6	103	10	10	8	95	95	295	20	20	12	283	283
0.7	110	6	6	5	105	105	324	18	18	14	310	310
0.8	145	4	4	7	138	138	351	21	21	19	332	332
0.9	113	7	6	18	95	94	336	24	22	34	302	300
1	153	8	7	14	139	138	343	25	21	24	319	315
1.1	109	3	3	8	101	101	272	16	11	16	256	252
1.2	112	7	6	7	105	104	242	18	14	18	224	220
1.3	88	4	3	8	80	79	207	8	6	17	190	188
1.4	73	1	0	9	64	63	149	6	4	17	132	130
1.5	54	2	1	6	48	47	122	4	3	12	110	109
1.6	34	6	6	3	31	31	91	9	7	9	82	81
1.7	34	2	1	3	31	31	69	3	2	7	62	62
1.8	25	2	2	3	22	22	60	8	7	5	55	54
1.9	25	1	1	3	22	22	46	2	2	5	41	41
2	12	2	2	3	8	8	34	6	5	7	25	25
2.1	5	5	5	5	0	0	11	11	10	11	2	2
2.2	6	6	4	5	0	0	29	29	27	28	1	0
2.3	4	4	4	4	0	0	11	11	11	11	0	0
2.4	4	4	4	4	0	0	10	10	9	9	1	0
2.5	1	1	1	1	0	0	2	2	2	2	0	0
2.6	3	3	3	3	1	0	7	7	7	7	0	0
2.7	2	2	1	1	0	0	8	8	6	6	2	0
2.8	2	2	2	2	0	0	3	3	3	3	0	0
2.9	0	0	0	0	0	0	2	2	2	2	0	0
3	0	0	0	0	0	0	5	5	5	5	0	0
3.1	2	2	2	2	0	0	4	4	4	4	0	0
3.3	1	1	1	1	0	0	3	3	3	3	0	0
3.4	0	0	0	0	0	0	1	1	1	1	0	0
3.5	1	1	1	1	0	0	1	1	1	1	0	0
3.7	0	0	0	0	0	0	1	1	1	1	0	0
4.1	0	0	0	0	0	0	2	2	2	2	0	0
4.3	1	1	1	1	0	0	1	1	1	1	0	0
4.6	0	0	0	0	0	0	1	1	1	1	0	0
4.9	1	1	1	1	0	0	2	2	2	2	0	0
6.7	0	0	0	0	0	0	1	1	1	1	0	0
7.2	0	0	0	0	0	0	1	1	1	1	0	0
10.15	1	1	1	1	0	0	1	1	1	1	0	0
Total	1362	169	158	141	1219	1211	3502	469	436	339	3163	3136
> 1 volt	600	64	56	85	513	508	1399	187	162	216	1183	1164
> 2 volts	34	34	31	32	1	0	107	107	101	103	6	2

Bobsrpt Table 3-1 (2) 3/14/99 6:10 PM

Table 3-2
Farley Unit 1 November 1998
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 15

Tube Support Plate	Steam Generator A					Steam Generator B				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
1H	238	6.65	1.20	4.69	0.34	207	7.17	1.02	5.74	0.28
2H	149	3.06	1.03	1.54	0.18	229	3.61	0.87	2.86	0.15
3H	177	2.58	0.93	1.13	0.12	204	2.33	0.84	0.80	0.06
4H	220	3.28	1.09	1.63	0.16	193	2.54	0.90	1.49	0.08
5H	111	2.79	1.08	0.87	0.17	89	1.67	0.87	0.82	0.07
6H	69	2.32	1.25	1.06	0.23	45	1.78	1.01	0.87	0.13
7H	7	1.28	1.03	0.35	0.08	14	1.48	0.87	0.66	0.18
7C	4	1.73	1.01	0.53	0.31	4	2.13	1.10	0.67	0.20
6C	5	1.34	0.80	0.18	0.08	2	1.01	0.87	0.16	-0.03
5C	11	1.71	0.97	0.64	0.21	6	0.73	0.60	0.12	0.07
4C	15	1.29	0.80	0.25	0.11	0	-	-	-	-
3C	2	0.49	0.41	0.17	0.10	3	0.88	0.57	0.20	0.11
2C	1	0.71	0.71	0.23	0.23	1	0.65	0.65	-0.02	-0.02
1C	8	1.04	0.57	0.16	0.05	1	0.55	0.55	-0.01	-0.01
Total	1017					998				

Tube Support Plate	Steam Generator C					Composite of All SGs				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
1H	186	4.82	0.97	3.52	0.17	631	7.17	1.07	5.74	0.27
2H	302	10.15	1.08	8.92	0.18	680	10.15	1.00	8.92	0.17
3H	298	3.01	1.07	1.82	0.12	679	3.01	0.96	1.82	0.10
4H	275	2.26	1.08	0.77	0.13	688	3.28	1.03	1.63	0.13
5H	129	2.77	1.09	0.84	0.14	329	2.79	1.03	0.87	0.13
6H	59	1.86	1.05	0.43	0.11	173	2.32	1.12	1.06	0.16
7H	9	1.66	1.12	0.19	0.07	30	1.66	0.98	0.66	0.12
7C	3	0.98	0.75	0.13	0.04	11	2.13	0.97	0.67	0.20
6C	5	1.58	1.14	0.56	0.20	12	1.58	0.95	0.56	0.12
5C	0	-	-	-	-	17	1.71	0.84	0.64	0.16
4C	4	0.80	0.65	0.14	0.08	19	1.29	0.77	0.25	0.10
3C	1	0.72	0.72	-0.21	-0.21	6	0.88	0.54	0.20	0.05
2C	6	1.07	0.59	0.22	0.03	8	1.07	0.61	0.23	0.05
1C	0	-	-	-	-	9	1.04	0.57	0.16	0.04
Total	1277					3292				

Table 3-3
Farley Unit 1 November 98
Signal Growth Statistics For Cycle 15 on an EFPY Basis

Delta Volts	Steam Generator A			Steam Generator B			Steam Generator C			Cumulative		
	Cycle 14	Cycle 15		Cycle 14	Cycle 15		Cycle 14	Cycle 15		Cycle 14	Cycle 15	
	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF
-0.4	0.002	0	0.0	0.002	0	0.0	0.002	0	0.0	0.002	0	0.0
-0.3	0.005	0	0.0	0.005	1	0.001	0.004	0	0.0	0.005	1	0.0003
-0.2	0.013	1	0.001	0.012	8	0.009	0.01	2	0.002	0.012	11	0.004
-0.1	0.129	25	0.026	0.12	52	0.061	0.104	23	0.02	0.117	100	0.034
0	0.533	139	0.162	0.564	263	0.325	0.622	239	0.207	0.576	641	0.229
0.1	0.846	333	0.49	0.856	319	0.644	0.875	529	0.621	0.86	1181	0.587
0.2	0.936	243	0.729	0.94	184	0.829	0.948	284	0.843	0.942	711	0.803
0.3	0.964	118	0.845	0.966	72	0.901	0.971	100	0.922	0.967	290	0.892
0.4	0.979	71	0.914	0.98	29	0.93	0.983	46	0.958	0.981	146	0.936
0.5	0.985	39	0.953	0.986	27	0.957	0.988	30	0.981	0.987	96	0.965
0.6	0.989	18	0.971	0.99	14	0.971	0.991	9	0.988	0.99	41	0.978
0.7	0.993	7	0.977	0.993	8	0.979	0.994	2	0.99	0.993	17	0.983
0.8	0.996	7	0.984	0.996	7	0.986	0.997	2	0.991	0.996	16	0.988
0.9	0.997	6	0.99	0.997	2	0.988	0.997	2	0.993	0.997	10	0.991
1	0.998	0	0.99	0.998	1	0.989	0.998	2	0.995	0.998	3	0.991
1.1	0.998	1	0.991	0.998	2	0.991	0.998	0	0.995	0.998	3	0.992
1.2	0.999	4	0.995	0.999	3	0.994	0.999	2	0.996	0.999	9	0.995
1.3	0.999	2	0.997	0.999	0	0.994	0.999	0	0.996	0.999	2	0.996
1.4	0.999	0	0.997	0.999	1	0.995	0.999	0	0.996	0.999	1	0.996
1.5	0.999	1	0.998	0.999	1	0.996	0.999	1	0.997	0.999	3	0.997
1.8	0.999	0	0.998	0.999	1	0.997	0.999	0	0.997	0.999	1	0.997
1.9	0.999	1	0.999	0.999	0	0.997	0.999	1	0.998	0.999	2	0.998
2	1.0	0	0.999	1.0	0	0.997	1.0	0	0.998	1.0	0	0.998
2.1		0	0.999		0	0.997		1	0.998		1	0.9982
2.3		0	0.999		1	0.998		0	0.998		1	0.9985
2.8		0	0.999		0	0.998		1	0.999		1	0.9988
3.2		0	0.999		1	0.999		0	0.999		1	0.9991
3.7		1	1.0		0	0.999		0	0.999		1	[illegible]994
4.5		0			1	1.0		0	0.999		1	0.9997
7		0			0			1	1.0		1	1.0
Total		1017			998			1277			3292	

Table 3-4
Farley Unit 1 - November 1998 Outage
Average Voltage Growth During Cycle 15

Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Percent Growth	
			Entire Cycle	Per EFPY #	Entire Cycle	Per EFPY #
	Composite of All Steam Generator Data					
Entire Voltage Range	3292	0.86	0.160	0.124	18.7%	14.5%
$V_{BOC} <$ .75 Volts	1411	0.55	0.117	0.090	21.1%	16.3%
$\geq$ .75 Volts	1881	1.08	0.192	0.149	17.8%	13.8%
	Steam Generator A					
Entire Voltage Range	1017	0.87	0.202	0.157	23.1%	17.9%
$V_{BOC} <$ .75 Volts	416	0.55	0.134	0.104	24.3%	18.8%
$\geq$ .75 Volts	601	1.10	0.249	0.193	22.7%	17.6%
	Steam Generator B					
Entire Voltage Range	998	0.77	0.137	0.106	17.8%	13.8%
$V_{BOC} <$ .75 Volts	527	0.55	0.098	0.076	17.8%	13.8%
$\geq$ .75 Volts	471	1.01	0.181	0.140	17.8%	13.8%
	Steam Generator C					
Entire Voltage Range	1277	0.91	0.144	0.112	15.8%	12.3%
$V_{BOC} <$ .75 Volts	468	0.56	0.122	0.095	21.8%	16.9%
$\geq$ .75 Volts	809	1.12	0.157	0.122	14.1%	10.9%
	Steam Generator					
Entire Voltage Range	0	0.00	0.000	0.000	#N/A	#N/A
$V_{BOC} <$ .75 Volts	0	0.00	0.000	0.000	#N/A	#N/A
$\geq$ .75 Volts	0	0.00	0.000	0.000	#N/A	#N/A

Based on Cycle 15 duration of 471.2 EFPD (1.29 EFPY)

Table 3-5
Farley Unit 1 November 1998
Average Voltage Growth for Cycle 15
Composite of All Steam Generator Data

Bobbin Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Average Percentage Growth	
			Entire Cycle	Per EFPY	Entire Cycle	Per EFPY
	Cycle 15 (1997 - 1998) - 471.2 EFPD					
Entire Voltage Range	3292	0.86	0.160	0.124	18.7%	14.5%
$V_{BOC} <$ .75 Volts	1411	0.55	0.117	0.090	21.1%	16.3%
≥ .75 Volts	1881	1.08	0.192	0.149	17.8%	13.8%
	Cycle 14 (1995 - 1997) - 482.1 EFPD					
Entire Voltage Range	3074	0.91	0.154	0.116	16.8%	12.8%
$V_{BOC} <$ .75 Volts	1173	0.57	0.111	0.084	19.6%	14.8%
≥ .75 Volts	1901	1.12	0.180	0.136	16.0%	12.1%
	Cycle 13 (1994 - 1995) - 489.4 EFPD					
Entire Voltage Range	2571	0.89	0.085	0.063	10%	7%
$V_{BOC} <$ .75	1024	0.56	0.101	0.075	18%	13%
≥ .75	1547	1.10	0.074	0.056	7%	5%
	Cycle 12 (1992 - 1994) - 442 EFPD					
Entire Voltage Range	1681	0.98	-0.01	-0.008	~ 0 %	~ 0 %
$V_{BOC} <$ .75	466	0.60	0.04	0.003	7%	6%
≥ .75	1215	1.13	-0.03	-0.023	~ 0 %	~ 0 %
	Cycle 11 (1991 - 1992) - 471 EFPD					
Entire Voltage Range	1267	0.85	0.22	0.171	26%	20%
$V_{BOC} <$ .75	546	0.57	0.21	0.163	37%	29%
≥ .75	721	1.08	0.23	0.178	21%	17%
	Cycle 10 (1989 - 1991)					
Entire Voltage Range	499	0.70	0.23	N/A	33%	N/A
$V_{BOC} <$ .75	306	0.51	0.24	N/A	47%	N/A
≥ .75	193	1.01	0.08	N/A	8%	N/A
	Cycle 9 (1988 - 1989)					
Entire Voltage Range	431	0.62	0.22	N/A	35%	N/A
	Cycle 8 (1986 - 1988)					
Entire Voltage Range	274	0.48	0.28	N/A	58%	N/A
	Cycle 7 (1985 - 1986)					
Entire Voltage Range	123	0.45	0.20	N/A	44%	N/A

Table 3-6
Farley Unit 1 November 1998
Summary of Largest Voltage Growth Rates for BOC-15 to EOC-15

Steam Generator				Bobbin Voltage			RPC	New
SG	Row	Col	Elevation	EOC	BOC	Growth	Confirmed ?	Indication ?
C	20	42	02H	10.15	1.23	8.92	Y	Y
B	2	75	01H	7.17	1.43	5.74	Y	N
A	2	86	01H	6.65	1.96	4.69	Y	Y
B	2	83	01H	4.9	0.79	4.11	Y	N
C	29	[illegible]	01H	4.82	1.3	3.52	Y	Y
B	2	[illegible]	02H	3.61	0.75	2.86	Y	N
C	28	5[illegible]	02H	4.21	1.53	2.68	Y	N
A	4	34	01H	4.04	1.65	2.39	Y	N
C	2	75	02H	3.44	1.07	2.37	Y	N
B	30	63	01H	4.03	1.77	2.26	Y	Y
B	22	36	03H	2	0.01	1.99	Y	Y
B	27	70	02H	2.98	1.1	1.88	Y	N
A	13	4	01H	2.92	1.08	1.84	Y	N
C	22	21	03H	2.61	0.79	1.82	Y	N
B	45	39	02H	2.66	0.95	1.71	Y	N
A	22	73	01H	3.33	1.7	1.63	Y	N
A	37	30	04H	3.28	1.65	1.63	Y	N
B	43	62	01H	3.23	1.68	1.55	Y	Y
A	2	83	02H	2.49	0.95	1.54	Y	Y
C	2	76	02H	3.04	1.51	1.53	Y	N
B	23	42	02H	2.86	1.36	1.5	Y	N
A	15	70	01H	3.08	1.59	1.49	Y	Y
B	39	27	04H	2.54	1.05	1.49	Y	N
A	24	35	01H	2.97	1.49	1.48	Y	Y
C	35	74	02H	3.21	1.76	1.45	Y	Y
A	2	55	02H	2.93	1.49	1.44	Y	N
B	29	78	01H	2.96	1.56	1.4	Y	N
B	25	59	01H	2.33	0.95	1.38	Y	Y
A	7	87	01H	2.89	1.52	1.37	Y	N
C	3	18	01H	2.06	0.78	1.28	Y	Y

Growth Table3-6 2/2/99 8:53 AM

Table 3-7
Farley Unit 1 1998 EOC-15 Evaluation for Probability of Prior Cycle Detection
Composite of All Steam Generator Data

Voltage Bin	New Indications		1997 Bobbin, Field Call in 1997 Inspection		1997 Inspection Bobbin	POPCD			
	1998 Inspection RPC Confirmed	1998 Inspection RPC Confirmed plus not Inspected	1998 Inspection RPC Confirmed	1998 Inspection RPC Confirmed plus not Inspected	1997 Inspection Confirmed and Plugged	RPC Confirmed		RPC Confirmed Plus Not Inspected	
						Frac.	Count	Frac.	Count
> 0 - 0.2	209	212	1	2	0	0.0	1 / 210	0.009	2 / 214
0.2 - 0.4	3	97	2	119	5	0.700	7 / 10	0.561	124 / 221
0.4 - 0.6	8	157	13	520	26	0.830	39 / 47	0.777	546 / 703
0.6 -0 .8	5	141	26	637	34	0.923	60 / 65	0.826	671 / 812
0.8 - 1.0	3	83	30	578	53	0.965	83 / 86	0.884	631 / 714
1.0 - 1.5	14	101	63	687	47	0.887	110 / 124	0.879	734 / 835
1.5 - 2.0	19	30	36	100	36	0.791	72 / 91	0.819	136 / 166
> 2.0	3	3	1	1	84	0.966	85 / 88	0.966	85 / 88
TOTAL	264	824	172	2644	285				

Table 3-8
Farley Unit 1
Analysis of RPC Data from 1997 and 1998 Inspections
Combined Data from All Steam Generators

Group of Indications	Total 1997 Inspection Bobbin Indication	Total 1998 Inspection Bobbin Indication	Total 1998 Inspection RPC Inspected	Total 1998 Inspection RPC Confirmed	Percent 1998 Inspection RPC Confirmed
Less than or Equal to 1.0 Volt in 1998 Inspection					
1997 Inspection Bobbin Left in Service	1542	1526	62	55	88.7
- 1997 Inspection RPC Confirmed	16	16	4	4	100.0
- 1997 Inspection RPC NDD	43	43	4	2	50.0
- 1997 Inspection RPC Not Inspected	1467	1467	54	49	90.7
- No 1998 Inspection Bobbin Indication*	16	-	-	-	-
New 1998 Inspection Indication	-	577	220	219	99.5
Sum of All 1998 Inspection Indication	1542	2103	282	274	97.2
Greater than 1.0 Volt in 1998 Inspection					
1997 Inspection Bobbin Left in Service	1165	1145	137	117	85.4
- 1997 Inspection RPC Confirmed	97	97	22	22	100.0
- 1997 Inspection RPC NDD	88	88	19	7	36.8
- 1997 Inspection RPC Not Inspected	960	960	96	88	91.7
- No 1998 Inspection Bobbin Indication*	20	-	-	-	-
New 1998 Inspection Indication	-	253	50	45	90.0
Sum of All 1998 Inspection Indication	1165	1398	187	162	86.6
All Voltages in 1998 Inspection					
1997 Inspection Bobbin Left in Service	2707	2671	199	172	86.4
- 1997 Inspection RPC Confirmed	113	113	26	26	100.0
- 1997 Inspection RPC NDD	131	131	23	9	39.1
- 1997 Inspection RPC Not Inspected	2427	2427	150	137	91.3
- No 1998 Inspection Bobbin Indication*	36	-	-	-	-
New 1998 Inspection Indication	-	830	270	264	97.8
Sum of All 1998 Inspection Indication	2707	3501	469	436	93.0

* Indications split is based on 1997 Inspection bobbin voltage

Figure 3-1
Farley Unit 1 November 1998 Outage
Bobbin Voltage Distributions at EOC-15 for Tubes in Service During Cycle 15

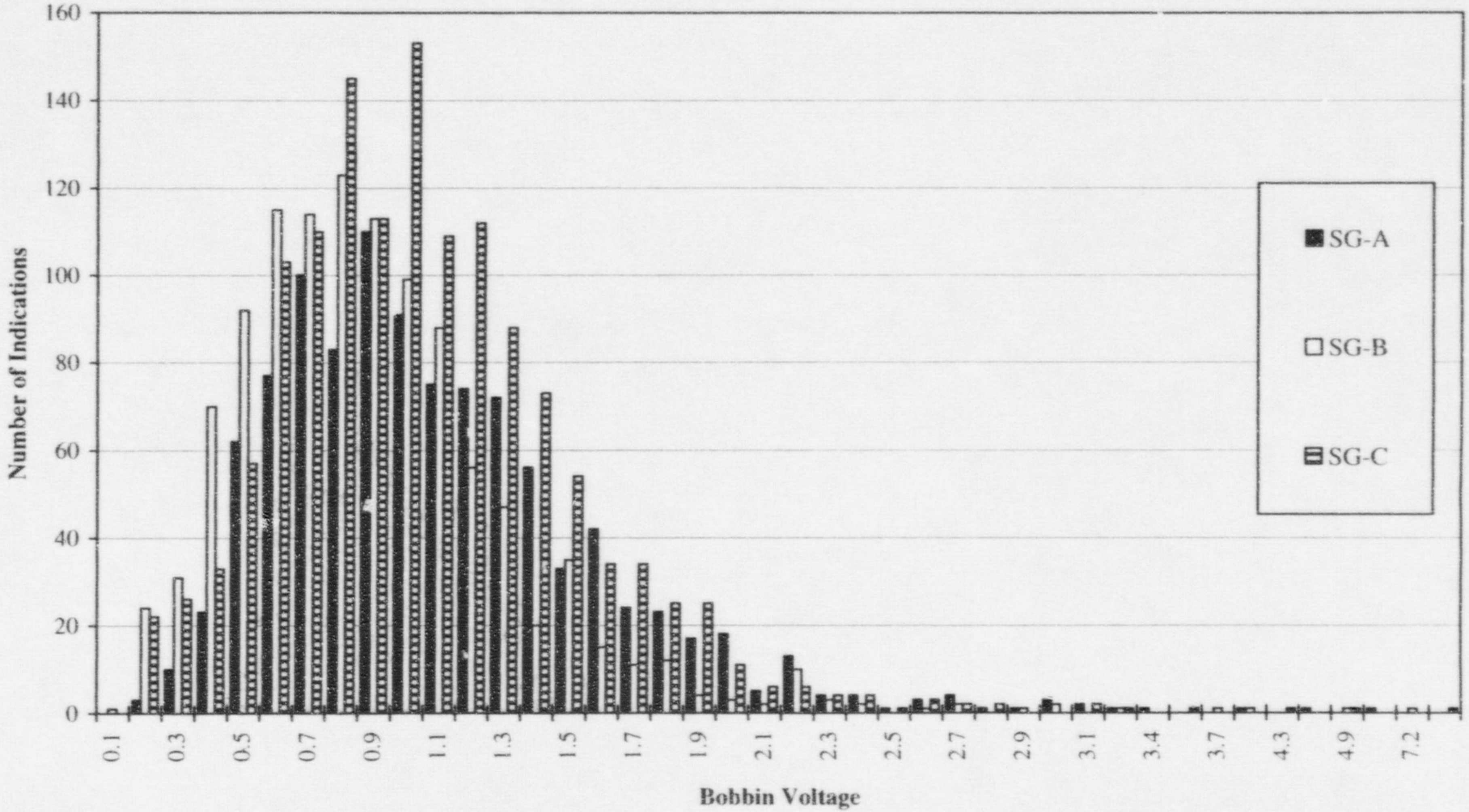


Figure 3-2
Farley Unit 1 November 1998 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 15 Service

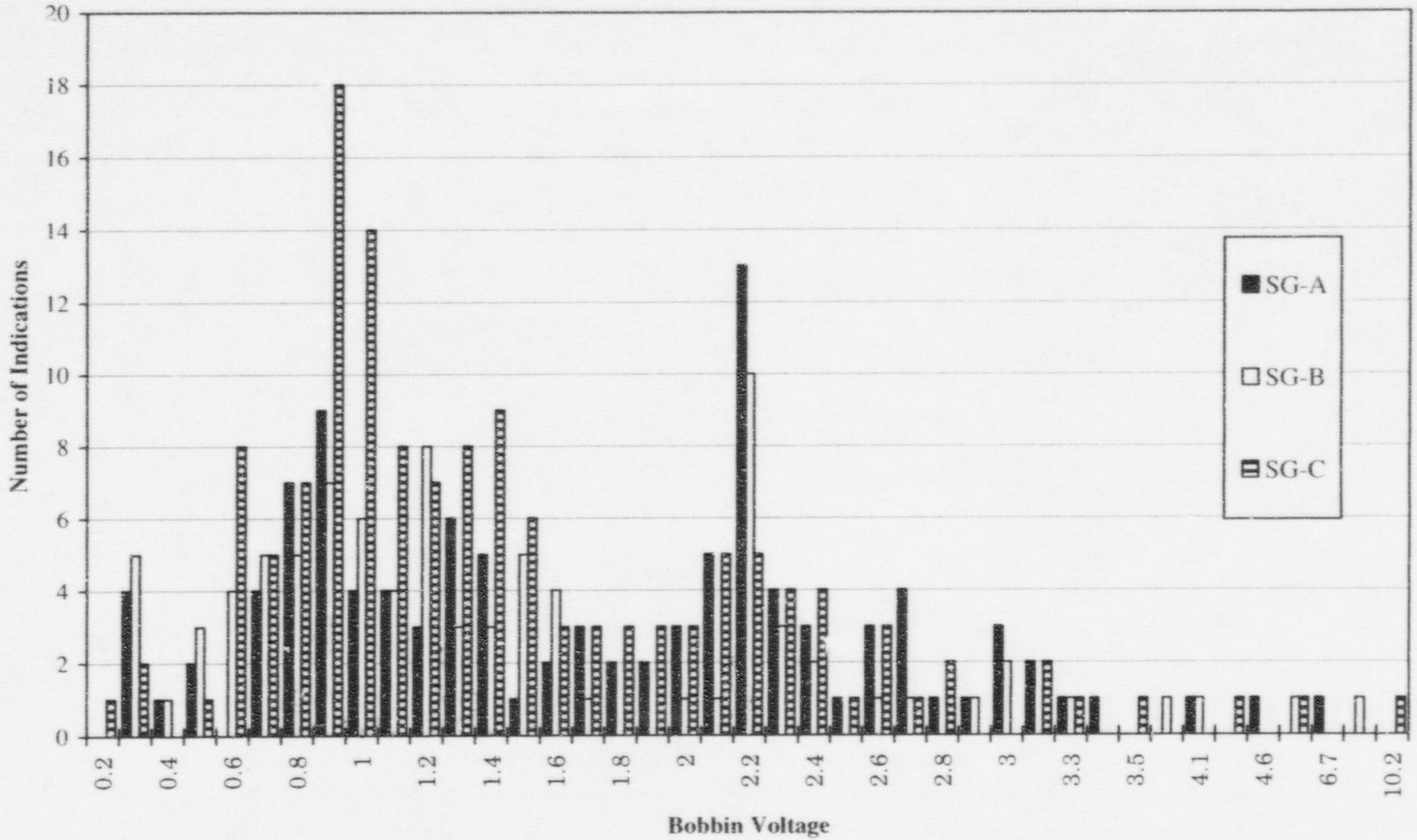


Figure 3-3
Farley Unit 1 November 1998 Outage
Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 16

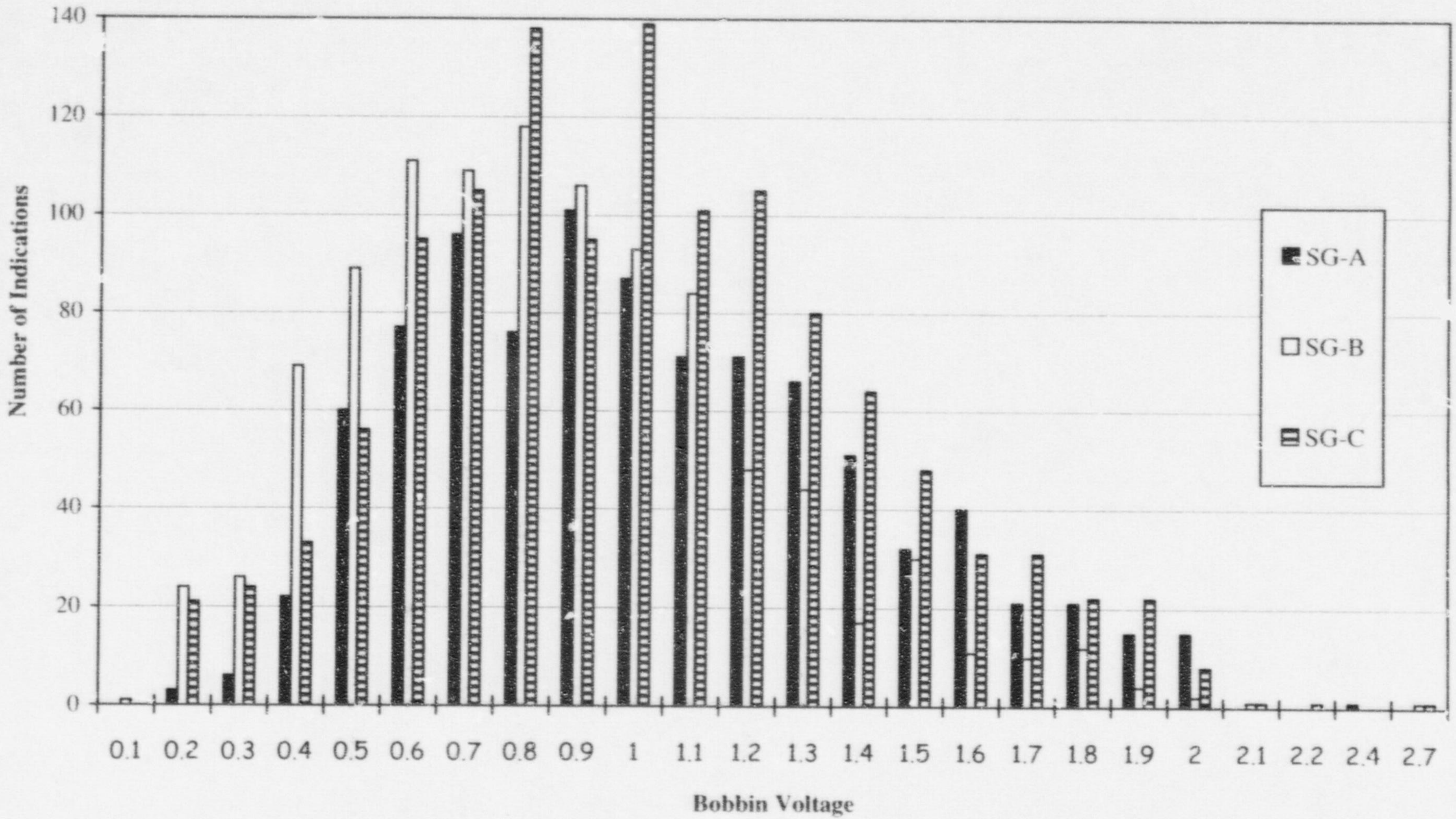


Figure 3-4
Farley Unit 1 - November 1998
ODSCC Axial Distributions for Tubes in Service During Cycle 15

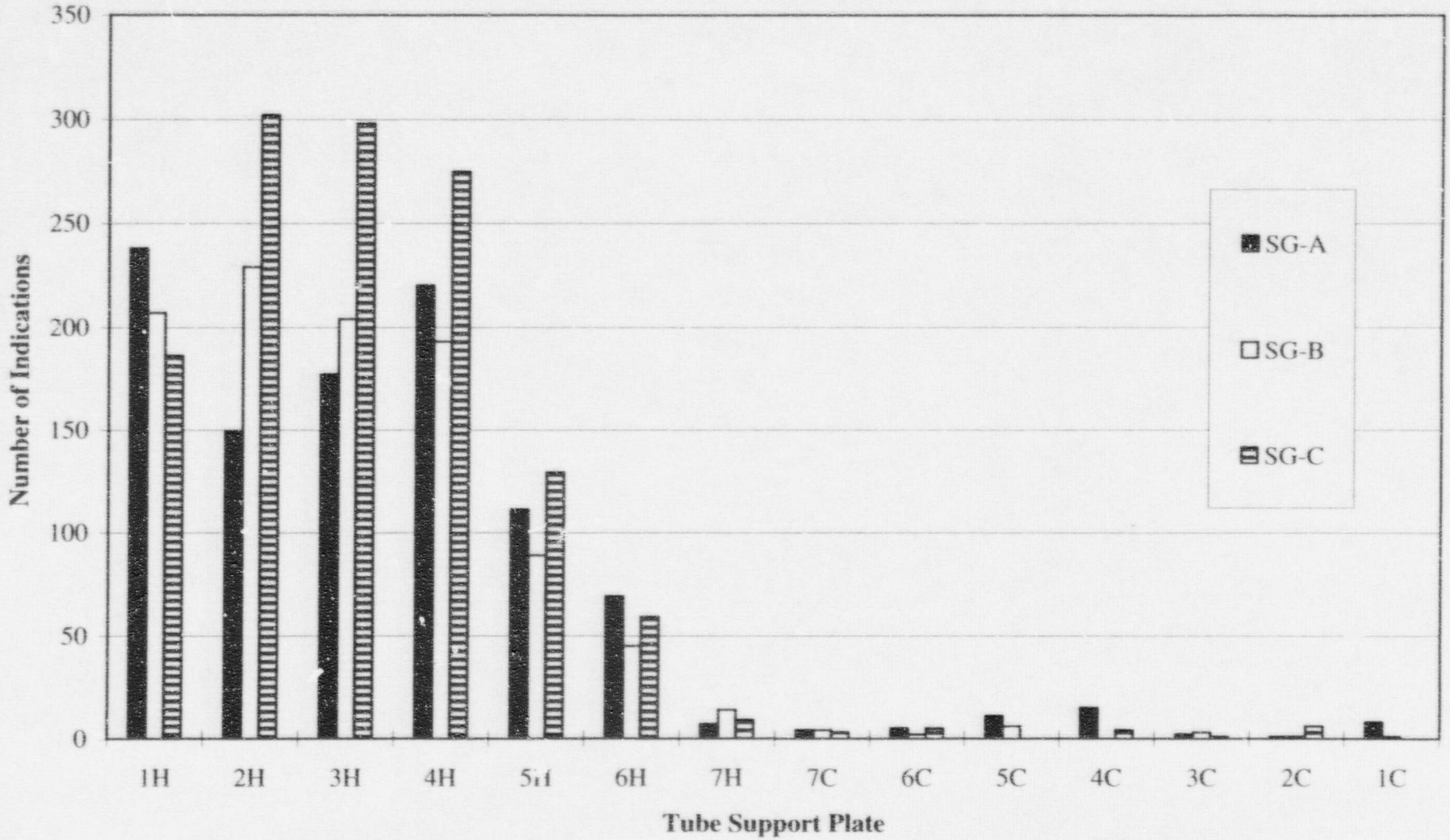


Figure 3-5
Farley Unit 1Cycle 15 (June. 1997 to October 1998)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

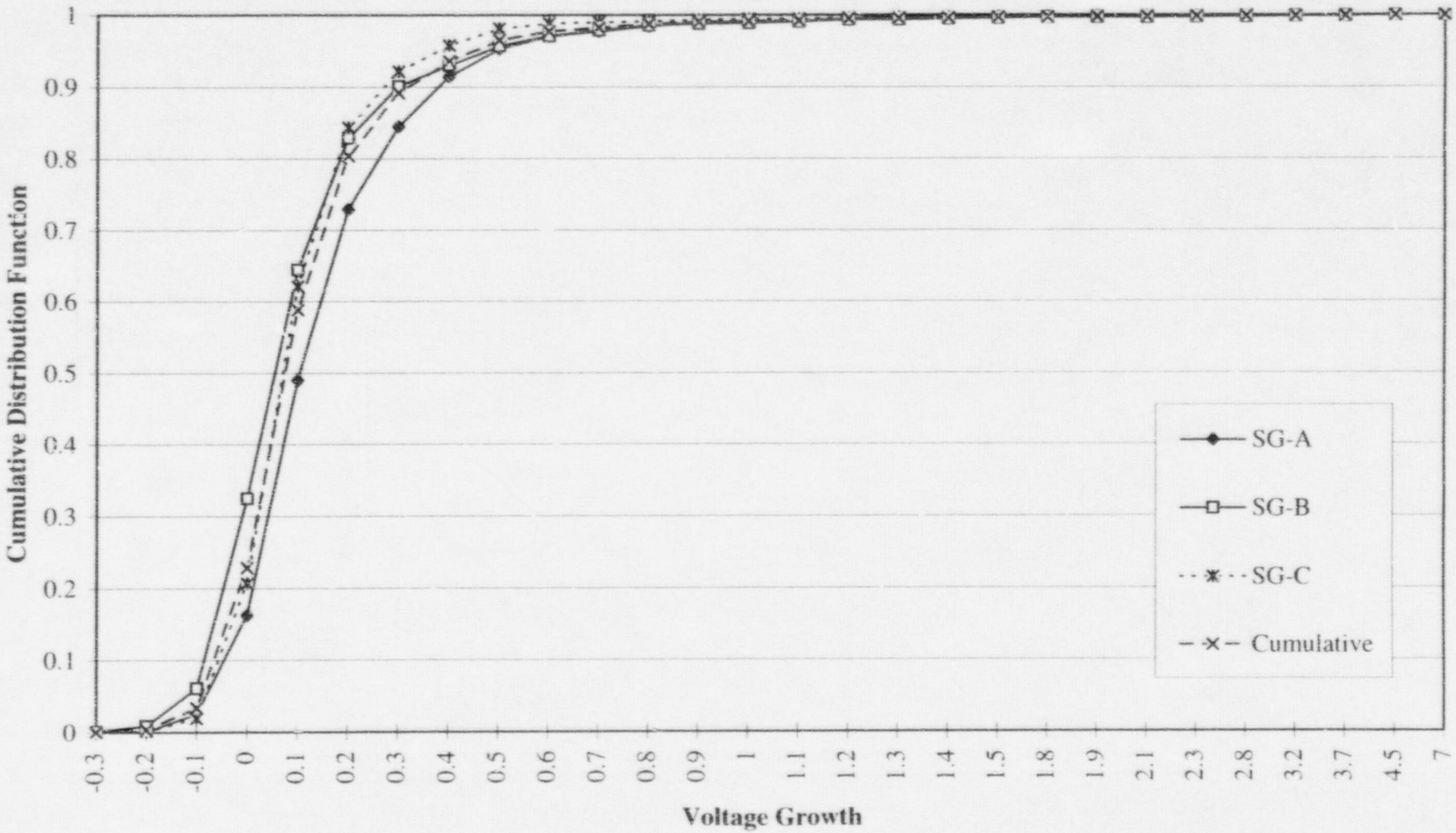


Figure 3-6
Farley Unit 1 - Cycle 15 (June. 1997 to October 1998)
Bobbin Signal Growth History - Cumulative Probability Distributions on an EFPY Basis
Composite of All Steam Generators

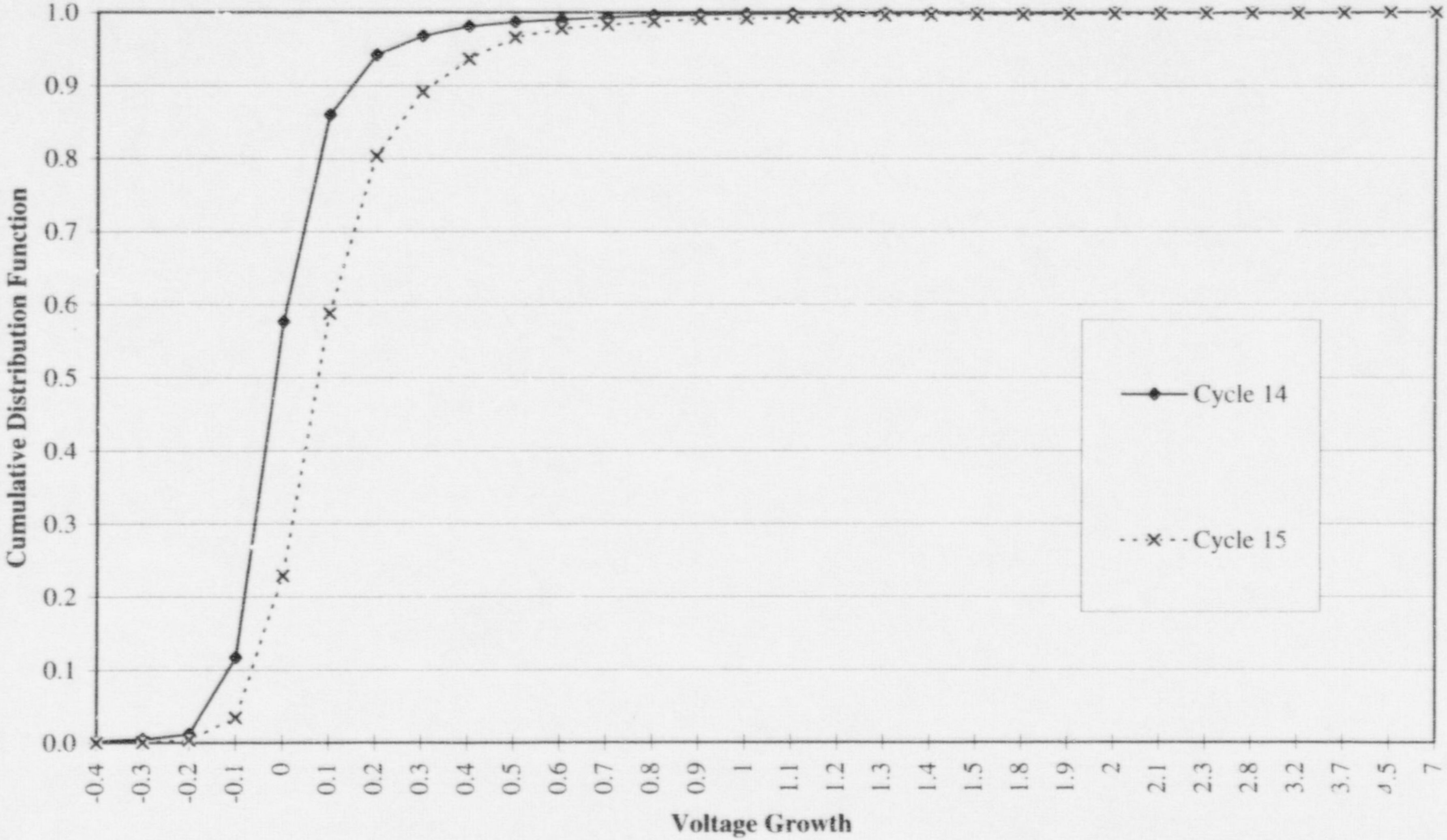


Figure 3-7
Farley Unit -1 October 1998 Outage
Voltage Growth During Cycle 15 vs BOC-15 voltage

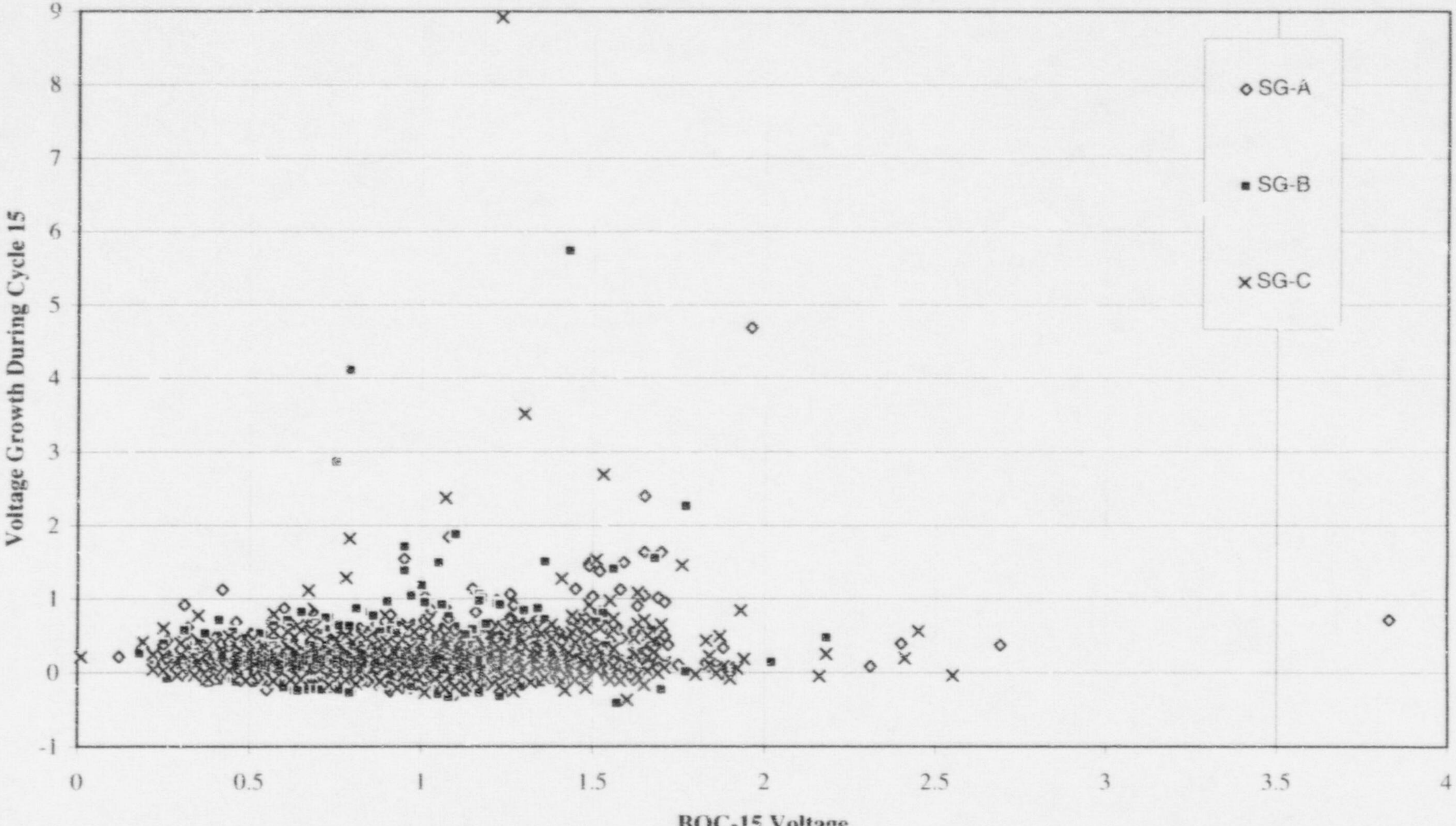
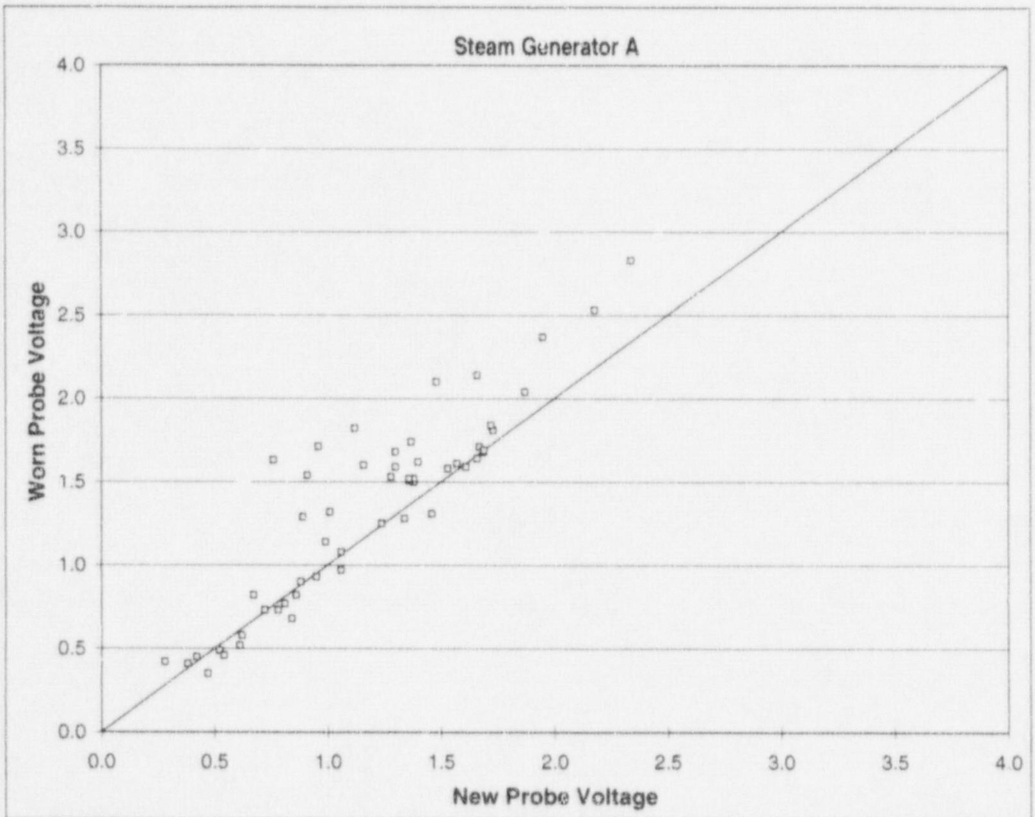
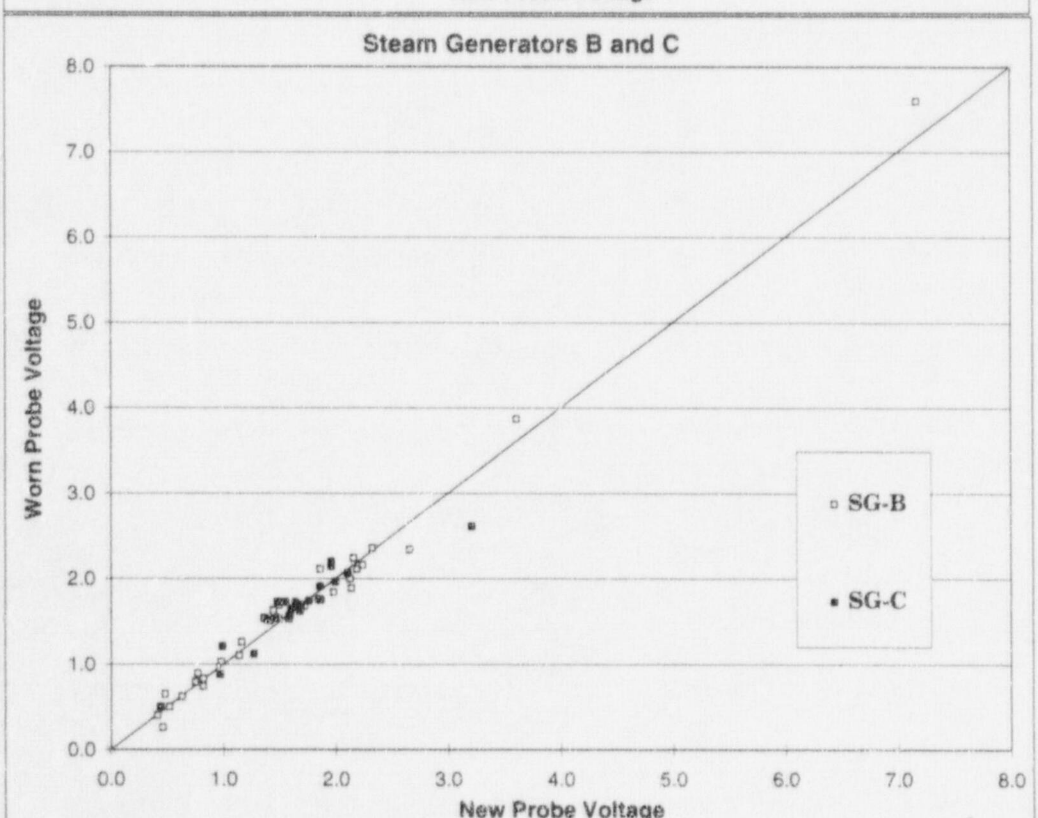


Figure 3-8
Farley Unit-1 EOC-15 Inspection
Comparison of Worn Probe Voltage Against New Probe Voltage





ProbeWear Figs-9 2/10/99 4:01 PM

Figure 3-9
Farley Unit-1 October 1998
Worn Probe Volts vs New Probe Volts

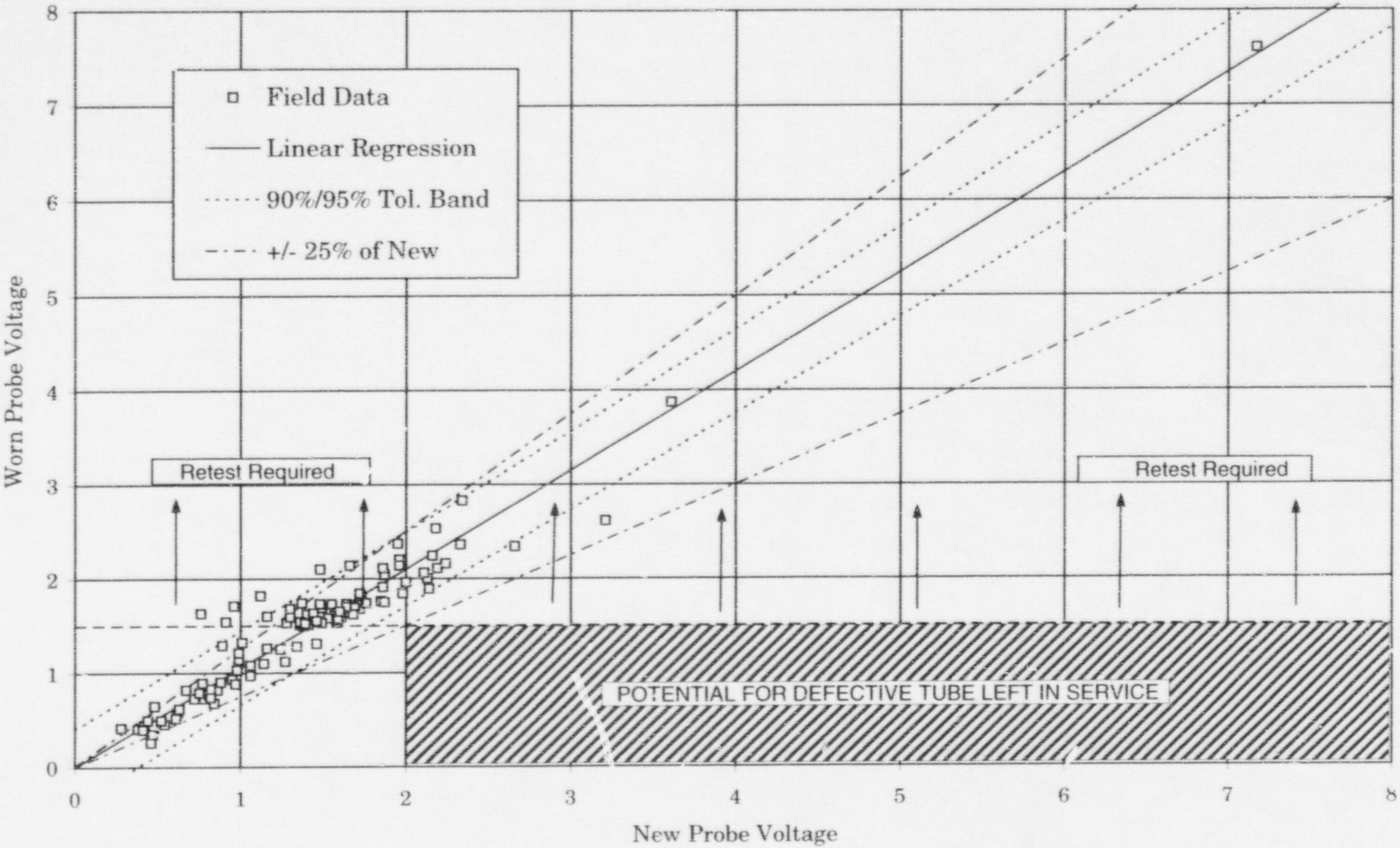
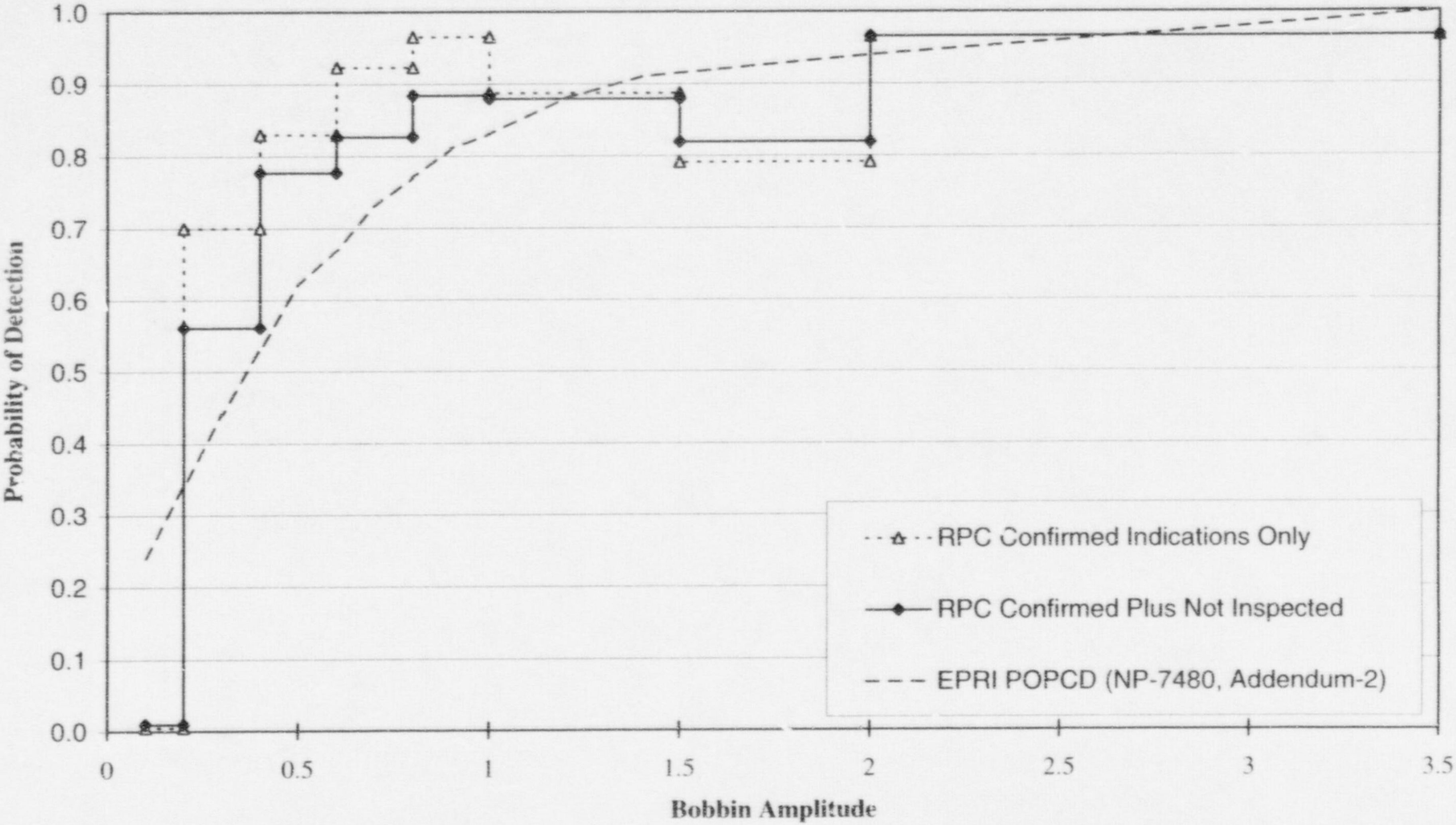
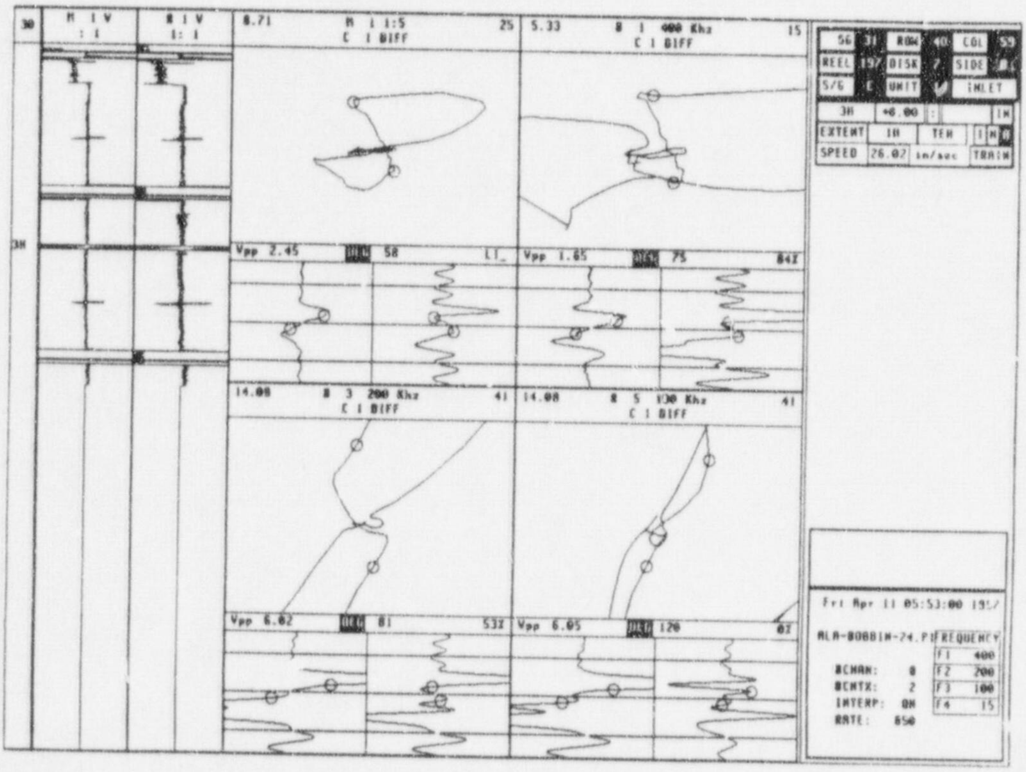


Figure 3-10
Farley Unit 1
1998 EOC-15 Evaluation for POPCD at EOC-14



PopcdlFig1|3/14/99|8:11 PM

Figure 3-11
Field and Reevaluated Bobbin Voltages from 1R14 for R40C59



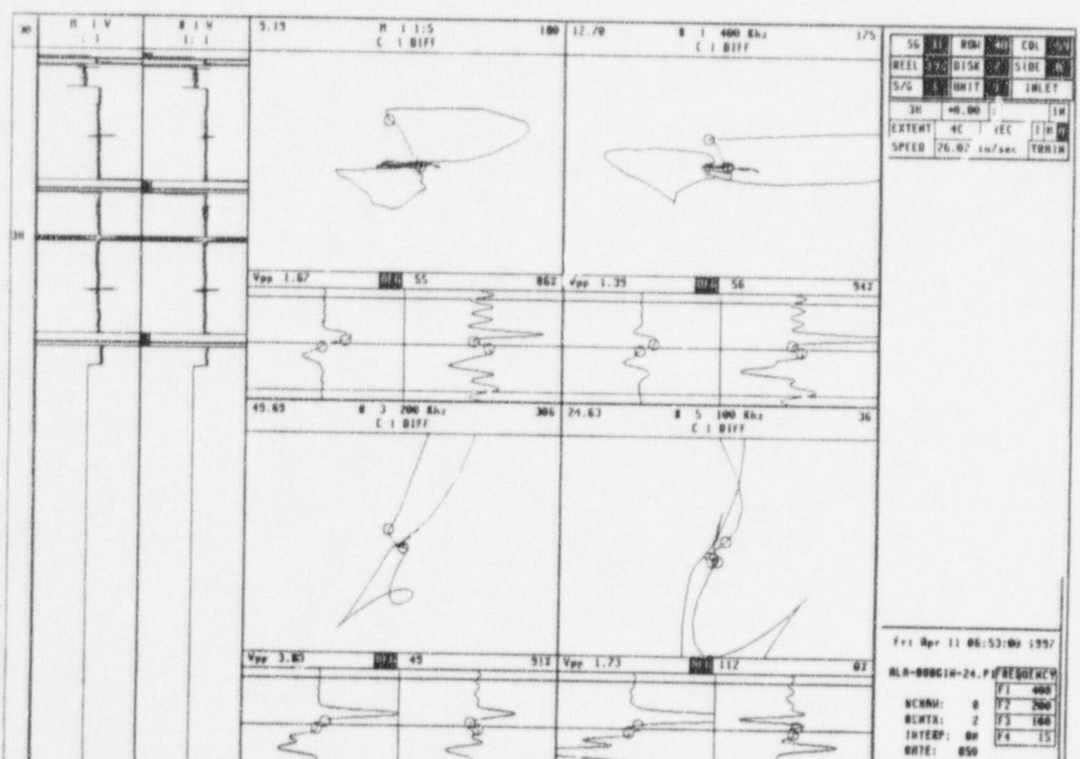
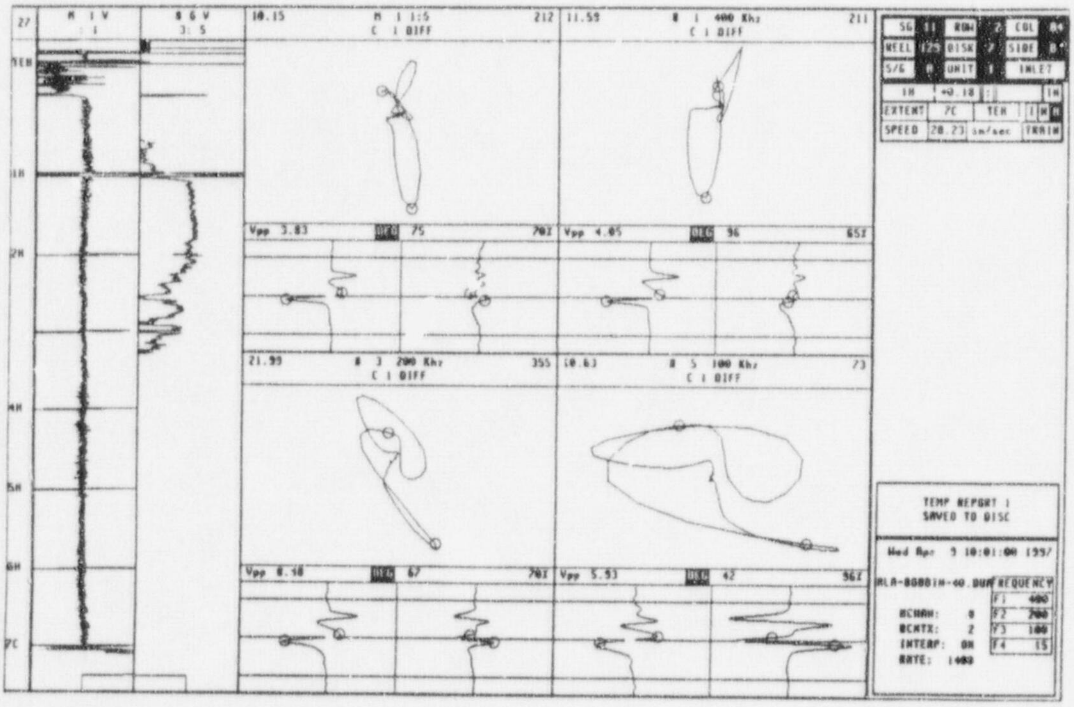


Figure 3-12
Field and Reevaluated Bobbin Voltages from 1R14 for R2C84 TSP 1H



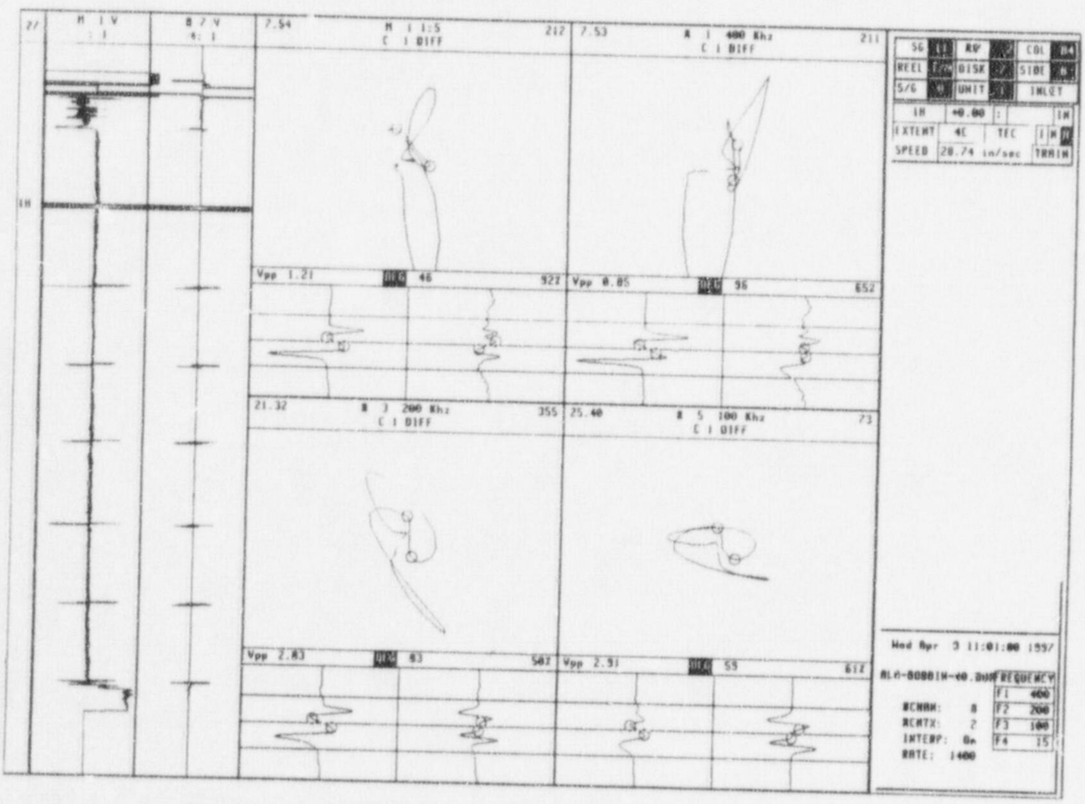
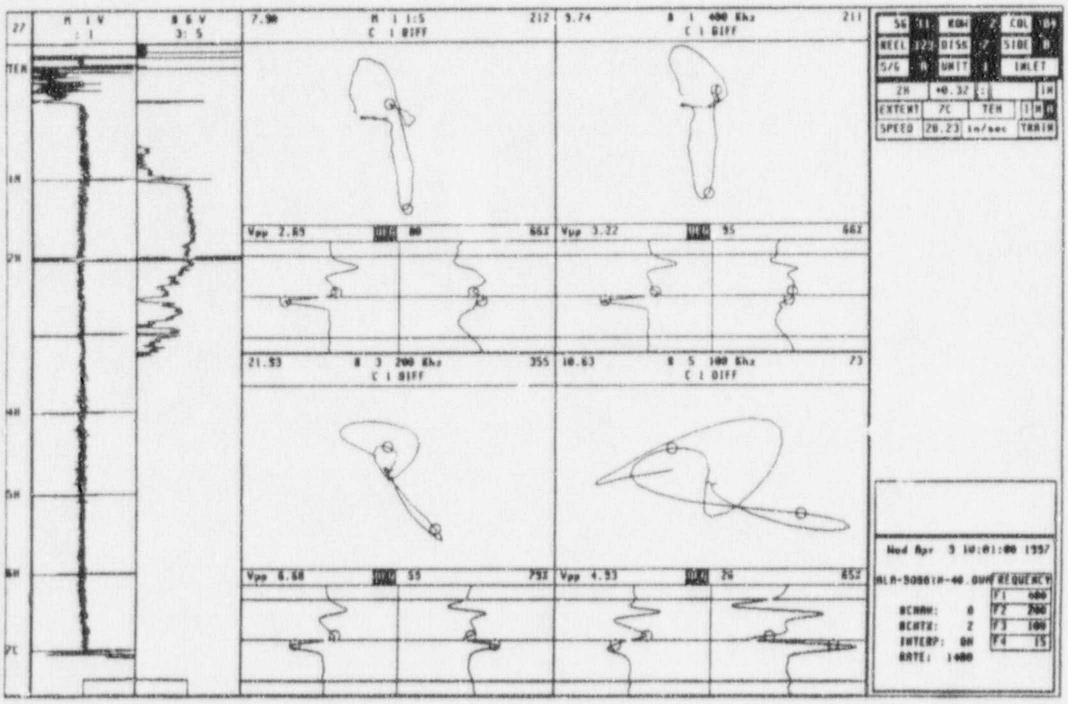
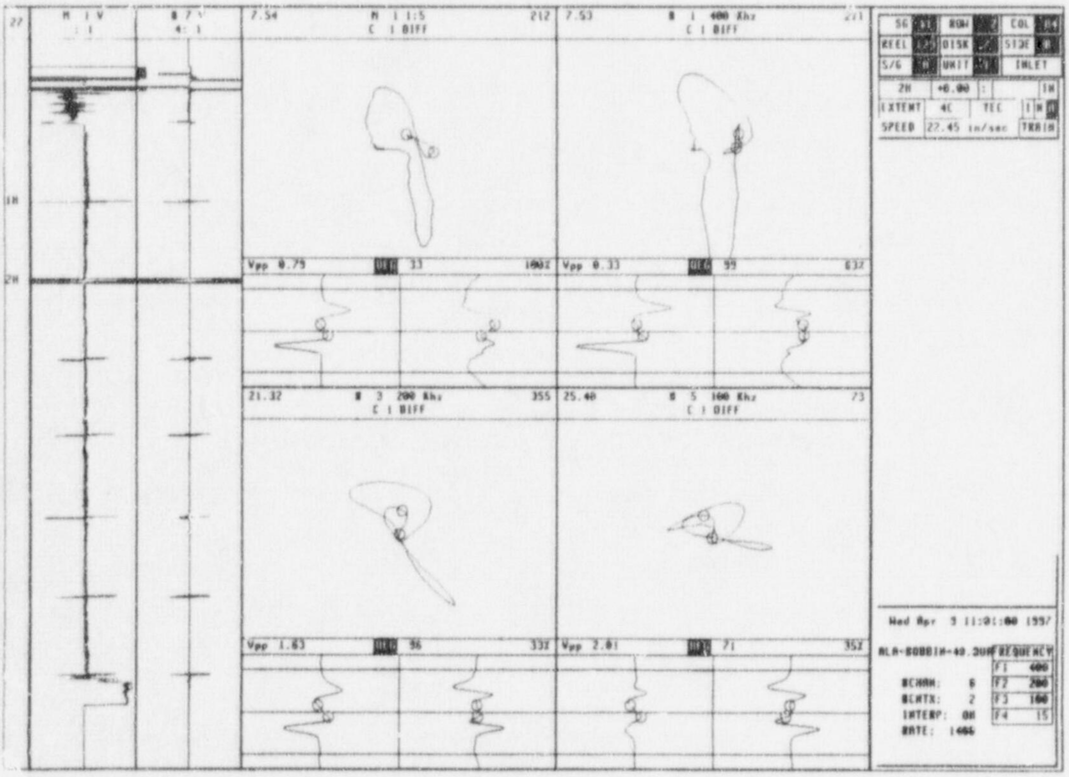


Figure 3-13
Field and Reevaluated Bobbin Voltages from 1R14 for R2C84 TSP 2H





4.0 DATABASE APPLIED FOR LEAK AND BURST CORRELATIONS

Correlations have been developed for the evaluation of ODSCC indications at TSP locations in steam generators which relate bobbin voltage amplitudes, free span burst pressure, probability of leakage and associated leak rates. The Westinghouse methodology used in the calculation of these parameters, documented in References 8.3 through 8.5, is consistent with NRC criteria and guidelines of References 8.1 and 8.2.

The database used for the leak and burst correlations that are applied in the analyses of this report are consistent with the NRC SER applicable to the Farley Unit-1 EOC-15 inspection. The EOC-15 projections reported originally in Reference 8.4 utilized the database documented in Reference 8.6. Since then, the database for 7/8" tubes has been updated to include data from the 1996 Plant A-2, 1997 Plant A-1 and 1996 Plant W-2 pulled examinations. This updated database along with leak and burst correlations based on it are presented in Reference 8.7, and they have been approved by the NRC (Reference 8.10). The EOC-15 projection for the limiting SG (which is SG-C) originally presented in Reference 8.4 was repeated using the latest database and correlations for 7/8" tubes so that those results can be compared with the corresponding results based on the actual measured EOC-15 voltages. The latest database for 7/8" tubes documented in Reference 8.7 was used to perform leak rate and burst probability projections for the ongoing cycle.

A leak rate correlation can now be applied to 7/8" tubes based on the p-value for the slope of the leak rate correlation on a one-sided basis meeting the Generic Letter 95-05 requirement. The following leak rate correlation is developed in Reference 8.7 for 7/8" tubes.

$$\text{LeakRate (l/hr)} = 10^{\left[-0.5269 + 0.9872 \times \log_{10}(volts)\right]}$$

The above leak rate correlation was used to perform EOC-16 SLB leak rate projections for all 3 SGs.

The leak rate data in the database represent room temperature measurements of leakage at prototypic SLB conditions (i.e., leakage at SLB conditions was condensed and measured at room temperature). Therefore, SLB leak rates calculated using the leak and burst correlations provide volumetric rates at room temperature.

The upper voltage repair limit applied at the EOC-16 inspection was developed from the leak and burst database of Reference 8.7, which was the database available two months prior to the inspection. The current structural limit is 8.4 volts. The allowance for voltage growth is 30%/EFPY, which bounds the Farley Unit-1 data and is the minimum growth allowance required by Generic Letter 95-05 (Reference 8.1). For the expected 1.14 EFPY for Cycle 16, the growth allowance becomes 34.2%. The allowance for NDE uncertainty is 20% per Generic Letter 95-05. The upper voltage repair limit is then 8. 4 volts/1.542 = 5.45 volts.

5.0 SLB ANALYSIS METHODS

Monte Carlo analyses are used to predict the EOC-16 voltage distributions and to calculate the SLB leak rates and tube burst probabilities for both the actual EOC-15 voltage distribution and the predicted EOC-16 voltage distribution. These methods are consistent with the requirements of the Farley Unit-1 NRC SER (Reference 8.2) and are described in the generic methods report of WCAP-14277, Revision 1 (Reference 8.3) and the prior reports for Farley Unit-1 (References 8.4 and 8.5), and are in accord with NRC Generic Letter 95-05 (Reference 8.1). Leak rates calculated with the WCAP-14277 methodology provide a volumetric leak rate at room temperature and they are compared with the allowable volumetric leak rate at room temperature.

At the time of last inspection (EOC-14), the leak rate database for 7/8" tubes did not satisfy the requirement for a SLB leak rate versus bobbin voltage correlation applicable then (p-value for the correlation slope parameter calculated on a two-sided basis less than 5%). Therefore, leak rate projections for the EOC-15 condition were carried out using a distribution of leak rate data independent of voltage. Two sets of calculations are available for EOC-15 SLB leak rate projections, both assuming leak rate to be independent of voltage.

1. Calculations based on the original leak rate analysis method presented in Section 4.6, Reference 8.3 for modeling voltage-independent leak rate.
2. An updated method that utilizes unbiased parameters for leak rate distribution independent of voltage.

The SLB leak rate projections based on the unbiased leak rate parameters are more realistic, and they were chosen for comparison with the results calculated using the actual EOC-15 voltages.

As mentioned in the previous section, a leak rate correlation can now be applied for 7/8" tubes based on the p-value for the slope of the leak rate correlation calculated on a one-sided basis meeting the Generic Letter 95-05 requirement. Therefore, leak rate analysis for the EOC-16 condition was also carried out using the leak rate vs. bobbin correlation shown in the previous section.

6.0 BOBBIN VOLTAGE DISTRIBUTIONS

This section describes prediction of the EOC voltage distribution used for evaluating tube leak and burst probabilities at the end of the operating period. The calculation consists of establishing the initial conditions (i.e., the bobbin indication population distribution) based on eddy current inspection data and projecting the indication growth over the operating period. Since indication growth is considered proportional to operating time, the limiting tube conditions occur at the end of any given time period or cycle.

The bobbin voltage distribution established for the BOC conditions is adjusted for measurement uncertainty using a quantity termed probability of detection, as described in the following paragraphs. Other input used for predicting the EOC voltage distribution and the results are presented below.

6.1 Probability of Detection

The number of bobbin indications used to predict tube leak rate and burst probability is obtained by adjusting the number of reported indications to account for detection uncertainty. This is accomplished by using a POD factor. Adjustments are also made for indications either removed from or returned to service. The calculation of projected bobbin voltage frequency distribution is based on a net total number of indications returned to service, defined as:

$$N_{Tot\ RTS} = \frac{N_i}{POD} - N_{Repaired} + N_{deplugged} ,$$

where:

$N_{Tot\ RTS}$	=	Number of bobbin indications being returned to service for the next cycle.
N_i	=	Number of bobbin indications (in tubes in service during the previous cycle) reported in the current inspection.
POD	=	Probability of Detection.
$N_{repaired}$	=	Number of N_i which are repaired (plugged) after the last cycle.
$N_{deplugged}$	=	Number of previously-plugged indications which are deplugged after the last cycle and are returned to service.

There were no deplugged tubes returned to service in the recent inspection.

The NRC generic letter (Reference 8.1) requires the application of a constant POD = 0.6 to define the BOC distribution for the EOC voltage projections, unless an alternate

POD is approved by the NRC.

6.2 Cycle Operating Time

The following operating period values are used in the voltage projection calculations:

Cycle 14 = 489.4 EFPD   Cycle 15 = 482.1 EFPD   Cycle 16 = 420 EFPD (estimated)

6.3 Predicted EOC-16 Voltage Distribution

Bobbin voltage projections start with a cycle initial voltage distribution which is projected to the corresponding cycle final voltage distribution, based on the growth rate adjusted for the anticipated cycle operating time period. The overall growth rates for each of the Farley Unit-1 steam generators during the last two operating periods, as represented by their CPDFs, are shown in Table 3-3. A Generic Letter 95-05 requirement is that limiting growth rate for the past two cycles of operation should be used in the projections. The 1997 - 1998 operation (Cycle 15) growth rates slightly exceed those of the 1995 - 1997 (Cycle 14) operation and are used to predict the EOC-16 bobbin voltage distributions. Further conservatism for the EOC-16 bobbin voltage prediction is provided by the use of the larger of the composite growth rate for all SGs or the SG-specific growth rate in projecting EOC voltages for each SG. The methodology used in the calculations of EOC bobbin voltage distributions is described in Reference 8.3. Growth data were represented by a histogram.

For each SG, the initial bobbin voltage distribution of indications being returned to service for the ongoing cycle (BOC-16) is derived from the actual EOC-15 inspection results adjusted for tubes that are taken out of service by plugging. The Cycle 16 bobbin voltage population data is summarized on Table 6-1. It shows voltage distributions for EOC-15 bobbin indications, the subsequent plugged indications (which were in service for Cycle 15 and then taken out of service, albeit not all for reasons of ODSCC at TSP), and the BOC-16 indications. Two BOC-16 voltage distributions are shown for each SG: one set based on a constant POD value of 0.6 as required by GL 95-05, and a second set using the voltage dependent generic POPCD data. The development of generic POPCD data is described in Reference 8.7 and the POPCD distribution used here is shown in Figure 6-1. Table 6-1 shows that POD=0.6 predicts many more EOC-16 indications than obtained with POPCD. This is a consequence of the Farley-1 EOC-15 population being dominantly above 0.5 volts for which POD=0.6 is lower than POPCD. It is shown in Section 7 for the earlier EOC-15 analyses that the use of POD=0.6 substantially overestimated the actual number of indications at EOC-15.

Table 6-2 provides the EOC-16 voltage distributions predicted using the BOC-16 voltage distribution shown in Table 6-1. As anticipated, the largest number of indications is predicted for SG-C, 2129 indications for a constant POD of 0.6. The assumed BOC-16 and predicted EOC-16 bobbin voltage frequency distributions for all three SGs are also graphically illustrated on Figures 6-2 to 6-4. The largest bobbin voltage predicted for EOC-16 is in SG-C, and its magnitude is 10.8 volts for a constant POD of 0.6

6.4 Comparison of Predicted and Actual EOC-15 Voltage Distributions

The actual EOC-15 bobbin voltage distributions and the corresponding predictions presented in the last 90-day report (for EOC-15 inspection, Reference 8.4), are compared in Table 6-3 and on Figure 6-5. SG-C was predicted to be limiting for EOC-15 which is consistent with the actual measurement since this SG has the highest number of indications as well as the largest indication found in the EOC-15 inspection. The total number of indications for all SGs is overpredicted by 30% to 42% in the licensing-basis analysis with a POD of 0.6. Also, the licensing-basis analysis significantly overpredicted the actual EOC-15 bobbin voltage population over 1 volt as well as the population above 2 volts in all three SGs. The overprediction for indications in virtually every voltage size range demonstrates conservatism in the projection methodology. The EOC-15 voltage distributions based on the voltage-dependent POPCD also yields conservative results. While the total indication population for SGs B and C are under predicted by a small amount (3% to 10%), the indication population over 1 volt as well as the population above 2 volts are significantly overpredicted for all three SGs. Since it is the indication population over 1 volt that dominates the predicted leak rate and burst probability, it is concluded the voltage-dependent POPCD yields conservative results.

Table 6-1
Farley Unit 1 November 1998
EOC-15 Bobbin and Assumed BOC-16 Bobbin Distributions in SLB Leak Rate and Tube Burst Analyses

Voltage Bin	Steam Generator A				Steam Generator B				Steam Generator C			
	EOC - 15		BOC - 16		EOC - 15		BOC - 16		EOC - 15		BOC - 16	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.1	0	0	0.0	0.0	1	0	1.7	4.2	0	0	0.0	0.0
0.2	3	0	5.0	8.8	24	0	40.0	70.6	22	1	35.7	63.7
0.3	10	4	12.7	18.7	31	5	46.7	65.5	26	2	41.3	57.1
0.4	23	1	37.3	42.4	70	1	115.7	131.1	33	0	55.0	62.3
0.5	62	2	101.3	98.0	92	3	150.3	145.4	57	1	94.0	90.9
0.6	77	0	128.3	114.9	115	4	187.7	167.6	103	8	163.7	145.7
0.7	100	4	162.7	133.0	114	5	185.0	151.2	110	5	178.3	145.7
0.8	83	7	131.3	100.8	123	5	200.0	154.7	145	7	234.7	181.3
0.9	110	9	174.3	126.8	113	7	181.3	132.5	113	18	170.3	121.5
1	91	4	147.7	105.6	99	6	159.0	113.3	153	14	241.0	170.3
1.1	75	4	121.0	83.7	88	4	142.7	98.9	109	8	173.7	119.5
1.2	74	3	120.3	81.1	56	8	85.3	55.6	112	7	179.7	120.3
1.3	72	6	114.0	74.4	47	3	75.3	49.5	88	8	138.7	90.3
1.4	56	5	88.3	56.5	20	3	30.3	19.0	73	9	112.7	71.2
1.5	33	1	54.0	35.1	35	5	53.3	33.3	54	6	84.0	53.0
1.6	42	2	68.0	43.7	15	4	21.0	12.3	34	3	53.7	34.0
1.7	24	3	37.0	22.9	11	1	17.3	10.9	34	3	53.7	33.8
1.8	23	2	36.3	22.7	12	0	20.0	12.9	25	3	38.7	23.9
1.9	17	2	26.3	16.2	4	0	6.7	4.3	25	3	38.7	23.7
2	18	3	27.0	16.1	3	1	4.0	2.2	11	3	15.3	8.7
2.1	5	5	3.3	0.3	2	1	2.3	1.1	6	5	5.0	1.4
2.2	13	13	8.7	0.7	10	10	6.7	0.5	6	5	5.0	1.3
2.3	4	4	2.7	0.2	3	3	2.0	0.2	4	4	2.7	0.2
2.4	4	3	3.7	1.2	2	2	1.3	0.1	4	4	2.7	0.2
2.5	1	1	0.7	0.0	0	0	0.0	0.0	1	1	0.7	0.0
2.6	3	3	2.0	0.1	1	1	0.7	0.0	3	3	2.0	0.1
2.7	4	4	2.7	0.1	2	1	2.3	1.1	2	1	2.3	1.1
2.8	1	1	0.7	0.0	0	0	0.0	0.0	2	2	1.3	0.1
2.9	1	1	0.7	0.0	1	1	0.7	0.0	0	0	0.0	0.0
3	3	3	2.0	0.1	2	2	1.3	0.0	0	0	0.0	0.0
3.1	2	2	1.3	0.0	0	0	0.0	0.0	2	2	1.3	0.0
3.3	1	1	0.7	0.0	1	1	0.7	0.0	!	1	0.7	0.0
3.4	1	1	0.7	0.0	0	0	0.0	0.0	0	0	0.0	0.0
3.5	0	0	0.0	0.0	0	0	0.0	0.0	1	1	0.7	0.0
3.7	0	0	0.0	0.0	1	1	0.7	0.0	0	0	0.0	0.0
4.1	1	1	0.7	0.0	1	1	0.7	0.0	0	0	0.0	0.0
4.3	0	0	0.0	0.0	0	0	0.0	0.0	1	1	0.7	0.0
4.6	1	1	0.7	0.0	0	0	0.0	0.0	0	0	0.0	0.0
4.9	0	0	0.0	0.0	1	1	0.7	0.0	1	1	0.7	0.0
6.7	1	1	0.7	0.0	0	0	0.0	0.0	0	0	0.0	0.0
7.2	0	0	0.0	0.0	1	1	0.7	0.0	0	0	0.0	0.0
10	0	0	0.0	0.0	0	0	0.0	0.0	1	1	0.7	0.0
Total	1039	107	1624.7	1193.9	1101	91	1744.0	1413.1	1362	141	2129.0	1603.1
> 1V	480	76	724.0	455.4	319	55	476.7	302.0	600	85	915.0	582.7
> 2V	46	45	31.7	2.8	28	26	20.7	3.1	35	32	26.3	4.4

Table 6-2 (Sheet 1 of 2)
Farley Unit 1 November 1998
Voltage Distribution Projection for EOC - 16

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C	
	Projected Number of Indications at EOC - 16					
	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD
0.1	0.04	0.06	0.76	1.48	0.37	0.62
0.2	0.90	1.44	8.88	14.79	7.46	12.25
0.3	3.99	5.70	24.09	35.67	19.63	29.44
0.4	12.63	15.16	48.01	60.42	32.79	42.69
0.5	31.58	32.92	81.33	89.23	52.56	58.15
0.6	59.67	56.68	115.43	113.67	82.24	79.60
0.7	88.53	78.24	143.32	129.61	117.46	103.48
0.8	111.40	92.81	161.67	136.53	148.97	122.59
0.9	126.77	100.41	169.68	135.61	171.16	133.50
1.0	135.05	102.75	167.46	128.45	183.27	137.05
1.1	136.29	100.52	155.90	115.77	186.30	135.02
1.2	131.59	94.70	137.25	99.46	180.52	127.92
1.3	123.00	86.71	115.13	81.71	167.26	116.33
1.4	111.85	77.49	93.09	64.88	148.78	101.84
1.5	99.00	67.67	73.63	50.47	127.73	86.27
1.6	85.55	57.70	57.41	38.81	106.80	71.31
1.7	72.39	48.29	44.38	29.60	87.53	57.83
1.8	60.37	39.81	33.98	22.43	70.69	46.15
1.9	49.75	32.34	25.82	16.83	56.23	36.31
2.0	40.27	25.74	19.45	12.45	43.97	27.98
2.1	31.92	19.94	14.58	9.06	33.65	21.03
2.2	24.89	15.04	10.92	6.51	25.21	15.37
2.3	19.05	11.07	8.19	4.64	18.60	11.00
2.4	14.39	7.97	6.18	3.30	13.61	7.76
2.5	10.78	5.63	4.70	2.34	9.89	5.39
2.6	8.08	3.96	3.61	1.72	7.23	3.75
2.7	6.13	2.78	2.81	1.26	5.36	2.62
2.8	4.69	1.97	2.23	0.97	4.03	1.88
2.9	3.64	1.39	1.80	0.75	3.09	1.36
3.0	2.87	0.99	1.47	0.60	2.40	1.01
3.1	2.29	0.72	1.22	0.47	1.90	0.76
3.2	1.84	0.52	1.01	0.38	1.52	0.59
3.3	1.49	0.38	0.84	0.30	1.23	0.46
3.4	1.20	0.28	0.70	0.24	1.00	0.37
3.5	0.96	0.20	0.58	0.19	0.82	0.29
3.6	0.77	0.14	0.50	0.16	0.67	0.23
3.7	0.61	0.10	0.43	0.14	0.55	0.19
3.8	0.49	0.07	0.38	0.12	0.46	0.16
3.9	0.39	0.05	0.33	0.11	0.40	0.15
4.0	0.32	0.04	0.30	0.10	0.35	0.13
4.1	0.26	0.03	0.28	0.10	0.31	0.11
4.2	0.22	0.02	0.26	0.09	0.28	0.11
4.3	0.19	0.01	0.24	0.03	0.27	0.10
4.4	0.16	0.01	0.22	0.08	0.25	0.10
4.5	0.15	0.02	0.20	0.08	0.24	0.10
4.6	0.15	0.03	0.19	0.08	0.22	0.09
4.7	0.17	0.07	0.19	0.08	0.21	0.08
4.8	0.21	0.10	0.18	0.07	0.21	0.08
4.9	0.22	0.11	0.16	0.07	0.20	0.08
5.0	0.22	0.11	0.15	0.06	0.19	0.08

Table 6-2 (Sheet 2 of 2)
Fariey Unit 1 November 1998
Voltage Distribution Projection for EOC - 16

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C	
	Projected Number of Indications at EOC - 16					
	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD
5.1	0.21	0.11	0.13	0.03	0.17	0.07
5.2	0.20	0.10	0.12	0.00	0.15	0.06
5.3	0.18	0.10	0.11	0.00	0.14	0.06
5.4	0.16	0.09	0.10	0.00	0.13	0.06
5.5	0.16	0.10	0.09	0.00	0.11	0.04
5.6	0.17	0.12	0.09	0.00	0.10	0.00
5.7	0.20	0.15	0.09	0.00	0.10	0.00
5.8	0.21	0.15	0.09	0.00	0.10	0.00
5.9	0.21	0.15	0.09	0.70	0.10	0.00
6.0	0.20	0.14	0.08	0.00	0.09	0.00
6.1	0.19	0.12	0.07	0.00	0.08	0.00
6.2	0.17	0.11	0.06	0.00	0.08	0.70
6.3	0.14	0.09	0.05	0.00	0.07	0.00
6.4	0.13	0.08	0.04	0.00	0.06	0.00
6.5	0.11	0.07	0.03	0.00	0.05	0.00
6.6	0.09	0.05	0.02	0.00	0.04	0.00
6.7	0.13	0.04	0.02	0.00	0.03	0.00
6.8	[illegible]	0.03	0.01	0.00	0.02	0.00
6.9	[illegible]	0.03	0.01	0.00	0.02	0.00
7.0	[illegible]	0.02	0.01	0.00	0.01	0.00
7.1	0.05	0.01	0.01	0.00	0.01	0.00
7.2	0.07	0.01	0.08	0.00	0.01	0.00
7.3	0.05	0.01	0.10	0.00	0.01	0.00
7.4	0.04	0.00	0.00	0.00	0.00	0.00
7.5	0.03	0.00	0.00	0.00	0.00	0.00
7.6	0.03	0.00	0.00	0.00	0.00	0.00
7.7	0.03	0.00	0.00	0.00	0.00	0.00
7.8	0.02	0.00	0.00	0.00	0.00	0.00
7.9	0.02	0.00	0.00	0.00	0.00	0.00
8.0	0.02	0.00	0.00	0.00	0.00	0.00
8.1	0.01	0.00	0.70	0.00	0.00	0.00
8.2	0.01	0.00	0.00	0.00	0.01	0.00
8.3	0.02	0.01	0.00	0.00	0.01	0.00
8.4	0.04	0.03	0.00	0.00	0.01	0.00
8.5	0.08	0.07	0.00	0.00	0.02	0.00
8.6	0.12	0.05	0.00	0.00	0.04	0.00
8.7	0.14	0.00	0.00	0.30	0.05	0.00
8.8	0.15	0.00	0.00	0.00	0.06	0.00
8.9	0.11	0.00	0.00	0.00	0.06	0.30
9.0	0.00	0.70	0.30	0.00	0.02	0.00
9.2	0.70	0.00	0.00	0.00	0.00	0.00
9.4	0.00	0.30	0.00	0.00	0.00	0.00
9.6	0.30	0.00	0.00	0.00	0.00	0.00
10.0	0.00	0.00	0.00	0.00	0.70	0.00
10.8	0.00	0.00	0.00	0.00	0.30	0.00
TOTAL	1624.68	1193.93	1744.02	1413.05	2129.03	1603.05
> 1 V	1054.12	707.76	823.39	567.59	1313.12	883.68
> 2 V	144.06	76.79	67.35	35.18	137.31	76.72

Table 6-3 (Sheet 1 of 2)
Farley Unit 1 November 1998
Comparison of Predicted and Actual EOC-15 Voltage Distributions

Voltage Bin	Steam Generator A			Steam Generator B			Steam Generator C		
	Number of Indications								
	EOC-15 Prediction		EOC-15 Actual	EOC-15 Prediction		EOC-15 Actual	EOC-15 Prediction		EOC-15 Actual
	POD = 0.6	POPCD		POD = 0.6	POPCD		POD = 0.6	POPCD	
0.1	0.00	0.00	0	0.00	0.00	1	0.00	0.00	0
0.2	0.02	0.02	3	0.05	0.06	24	0.02	0.02	22
0.3	0.54	0.65	10	1.01	1.27	31	0.30	0.37	26
0.4	3.77	4.18	23	6.65	7.56	70	1.71	1.93	33
0.5	14.45	14.98	62	24.41	25.50	92	7.21	7.25	57
0.6	34.59	33.16	77	55.96	54.25	115	20.66	19.19	103
0.7	62.70	56.27	100	96.34	87.66	114	45.93	40.31	110
0.8	91.57	77.29	83	131.39	112.71	123	77.83	65.14	145
0.9	114.29	91.40	110	155.40	126.11	113	108.47	86.9[illegible]	113
1.0	128.31	98.09	91	166.41	128.66	99	131.45	100.88	153
1.1	133.05	98.14	75	165.44	122.90	88	146.29	107.92	109
1.2	129.19	92.60	74	153.71	110.53	56	154.17	110.09	112
1.3	119.18	83.30	72	134.40	93.99	47	156.14	108.61	88
1.4	106.21	72.55	56	111.97	76.45	20	152.23	103.56	73
1.5	92.34	61.87	33	90.27	60.23	35	142.05	94.93	54
1.6	78.65	51.78	42	70.92	46.40	15	126.31	83.16	34
1.7	65.73	42.66	24	54.42	35.00	11	107.34	69.75	34
1.8	54.07	34.59	23	40.63	25.76	12	88.01	56.45	25
1.9	43.85	27.57	17	29.62	18.47	4	70.41	44.55	25
2.0	34.98	21.53	18	21.26	12.92	3	55.48	34.57	11
2.1	27.39	16.37	5	15.18	8.90	2	43.29	26.46	6
2.2	21.01	12.05	13	10.92	6.07	10	33.39	19.95	6
2.3	15.79	8.62	4	7.98	4.12	3	25.43	14.74	4
2.4	11.69	5.99	4	5.97	2.80	2	19.04	10.63	4
2.5	8.56	4.09	1	4.55	1.92	0	14.03	7.48	1
2.6	6.25	2.77	3	3.51	1.31	1	10.20	5.14	3
2.7	4.55	1.88	4	2.72	0.90	2	7.34	3.48	2
2.8	3.33	1.28	1	2.08	0.62	0	5.25	2.33	2
2.9	2.43	0.88	1	1.59	0.42	1	3.76	1.54	0
3.0	1.78	0.61	3	1.19	0.29	2	2.69	1.03	0
3.1	1.30	0.42	2	0.88	0.19	0	1.94	0.68	2
3.2	0.94	0.29	0	0.64	0.13	0	1.39	0.45	0
3.3	0.68	0.20	1	0.46	0.00	1	1.02	0.30	1
3.4	0.49	0.08	1	0.32	0.00	0	0.75	0.20	0
3.5	0.34	0.00	0	0.23	0.00	0	0.55	0.13	1
3.6	0.24	0.00	0	0.16	0.00	0	0.41	0.09	0
3.7	0.17	0.00	0	0.12	0.00	1	0.31	0.06	0
3.8	0.13	0.00	0	0.10	0.00	0	0.24	0.04	0
3.9	0.11	0.70	0	0.10	0.00	0	0.18	0.03	0
4.0	0.09	0.00	0	0.04	0.70	0	0.14	0.02	0

Table 6-3 (Sheet 2 of 2)
Farley Unit 1 November 1998
Comparison of Predicted and Actual EOC-15 Voltage Distributions

Voltage Bin	Steam Generator A			Steam Generator B			Steam Generator C		
	Number of Indications								
	EOC-15 Prediction		EOC-15 Actual	EOC-15 Prediction		EOC-15 Actual	EOC-15 Prediction		EOC-15 Actual
	POD = 0.6	POPCD		POD = 0.6	POPCD		POD = 0.6	POPCD	
4.1	0.08	0.00	1	0.00	0.00	1	0.11	0.01	0
4.2	0.07	0.00	0	0.00	0.00	0	0.08	0.01	0
4.3	0.06	0.00	0	0.00	0.00	0	0.07	0.00	1
4.4	0.05	0.00	0	0.00	0.00	0	0.05	0.00	0
4.5	0.04	0.00	0	0.70	0.00	0	0.04	0.00	0
4.6	0.04	0.00	1	0.00	0.00	0	0.03	0.00	0
4.7	0.03	0.00	0	0.00	0.00	0	0.02	0.00	0
4.8	0.02	0.00	0	0.00	0.00	0	0.02	0.00	0
4.9	0.02	0.00	0	0.00	0.00	1	0.01	0.00	1
5.0	0.01	0.00	0	0.00	0.00	0	0.01	0.00	0
5.1	0.01	0.00	0	0.00	0.00	0	0.01	0.00	0
5.2	0.01	0.00	0	0.00	0.00	0	0.00	0.00	0
5.3	0.01	0.00	0	0.00	0.00	0	0.00	0.00	0
6.3	0.04	0.00	0	0.00	0.00	0	0.00	0.00	0
6.4	0.09	0.00	0	0.00	0.00	0	0.00	0.00	0
6.7	0.00	0.00	1	0.00	0.00	0	0.00	0.00	0
6.9	0.70	0.00	0	0.00	0.00	0	0.00	0.00	0
7.2	0.00	0.00	0	0.00	0.00	1	0.00	0.00	0
10.0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1
12.9	0.00	0.00		0.00	0.00		0.01	0.01	
13.0	0.00	0.00		0.00	0.00		0.03	0.03	
13.1	0.00	0.00		0.00	0.00		0.08	0.03	
13.2	0.00	0.30		0.00	0.30		0.11	0.00	
13.3	0.00	0.00		0.00	0.00		0.13	0.00	
13.4	0.00	0.00		0.30	0.00		0.14	0.00	
13.5	0.30	0.00		0.00	0.00		0.14	0.70	
13.6	0.00	0.00		0.00	0.00		0.14	0.00	
13.7	0.00	0.00		0.00	0.00		0.18	0.00	
13.8	0.00	0.00		0.00	0.00		0.24	0.00	
13.9	0.00	0.00		0.00	0.00		0.01	0.00	
14.0	0.00	0.00		0.00	0.00		0.00	0.30	
14.1	0.00	0.00		0.00	0.00		0.70	0.00	
14.7	0.00	0.00		0.00	0.00		0.30	0.00	
TOTAL	1416.34	1019.16	1039	1570.00	1175.10	1101	1766.02	1231.46	1362
> 1 V	966.10	643.12	480	932.38	631.32	319	1372.44	909.46	600
> 2 V	108.85	56.53	46	59.74	28.67	28	174.01	95.87	35

Figure 6-1
EPRI Probability of Detection Distribution
Lower 95% Confidence Bound

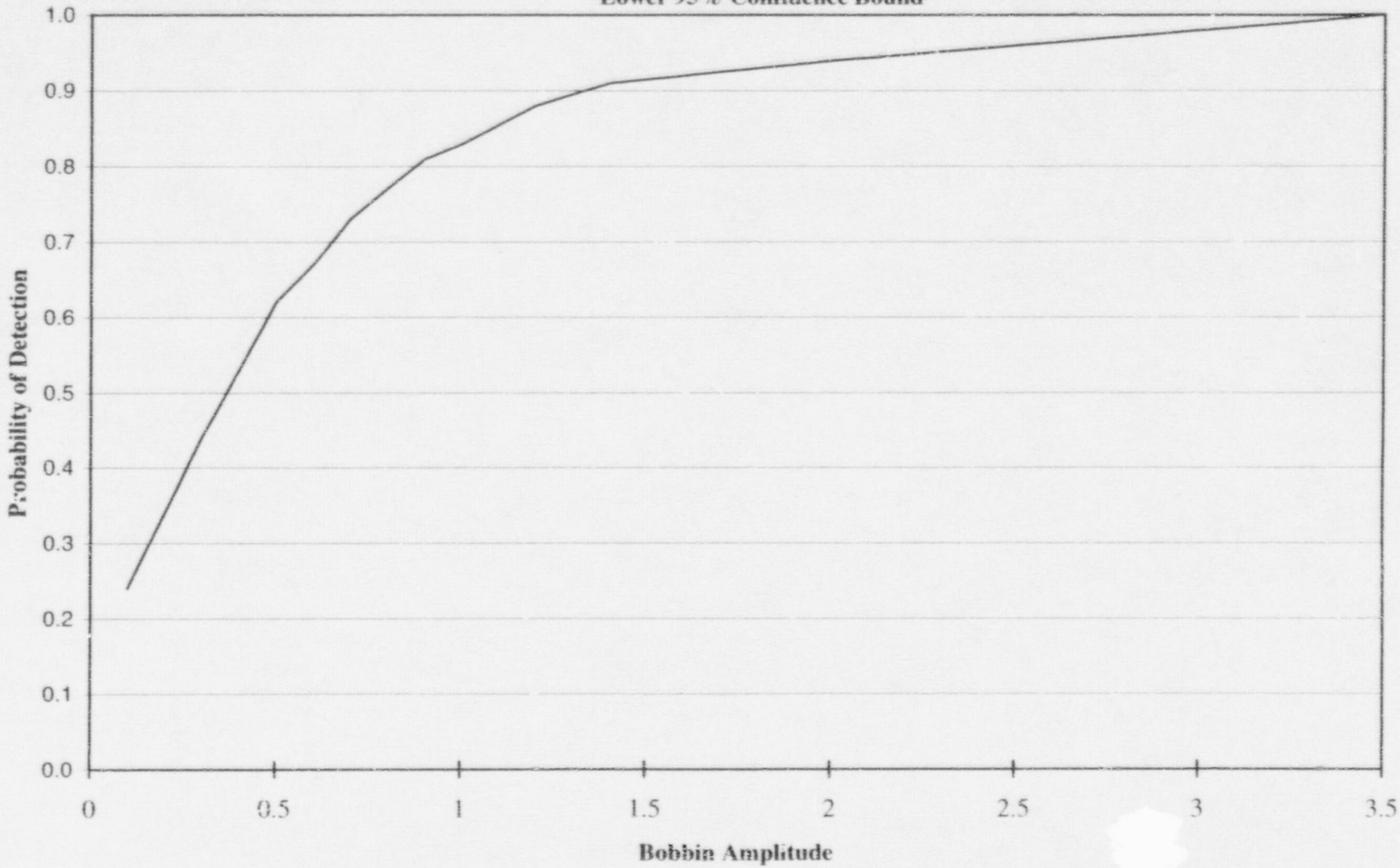


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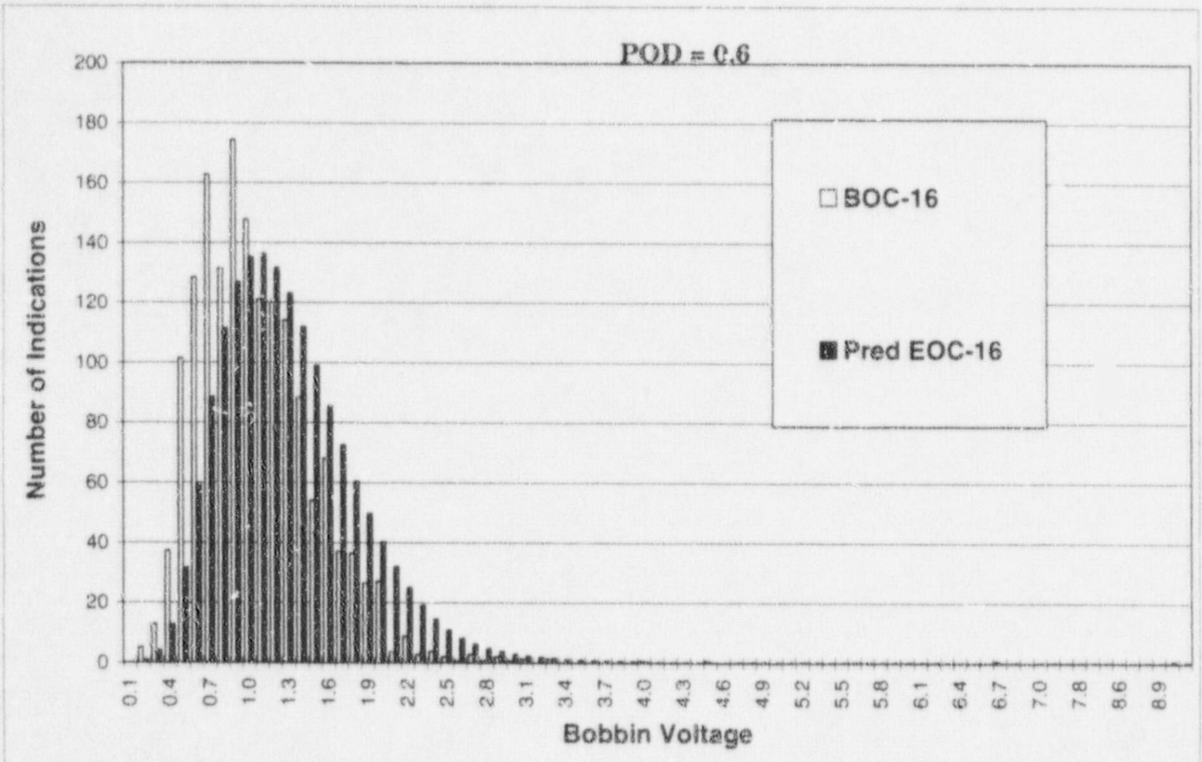
Figure 6-2
Farley Unit 1 SG-A
Predicted Bobbin Voltage Distribution for Cycle 16



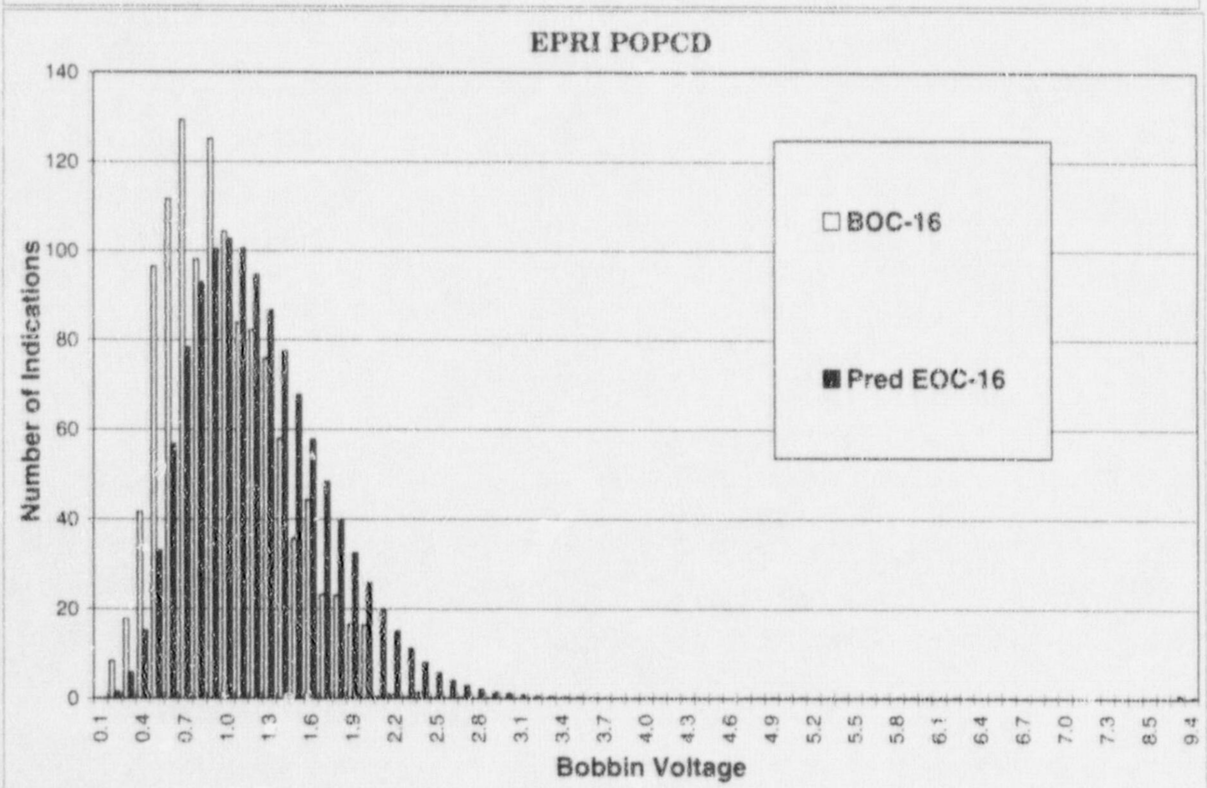


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Figure 6-3
Farley Unit 1 SG-B
Predicted Bobbin Voltage Distribution for Cycle 16

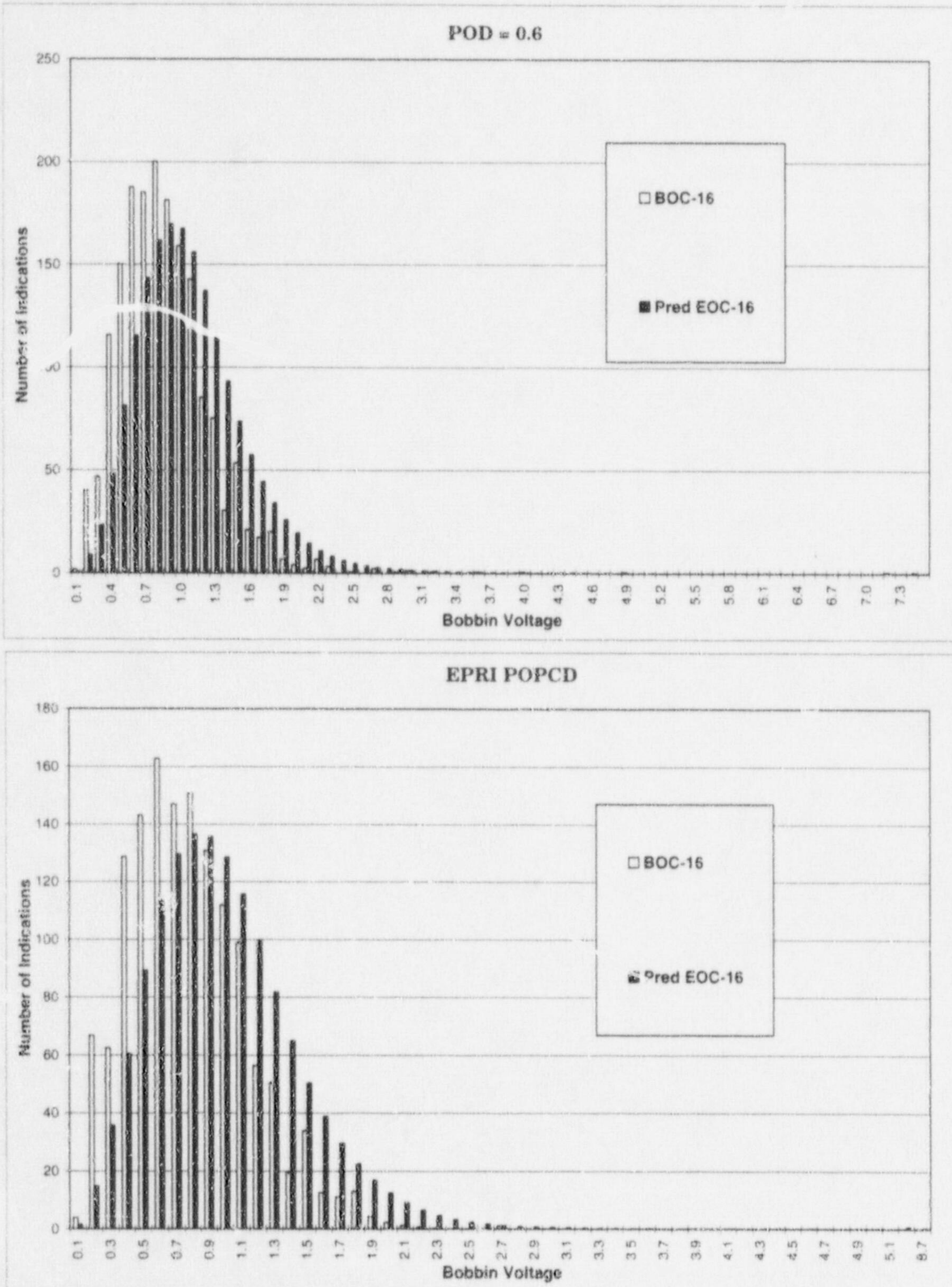
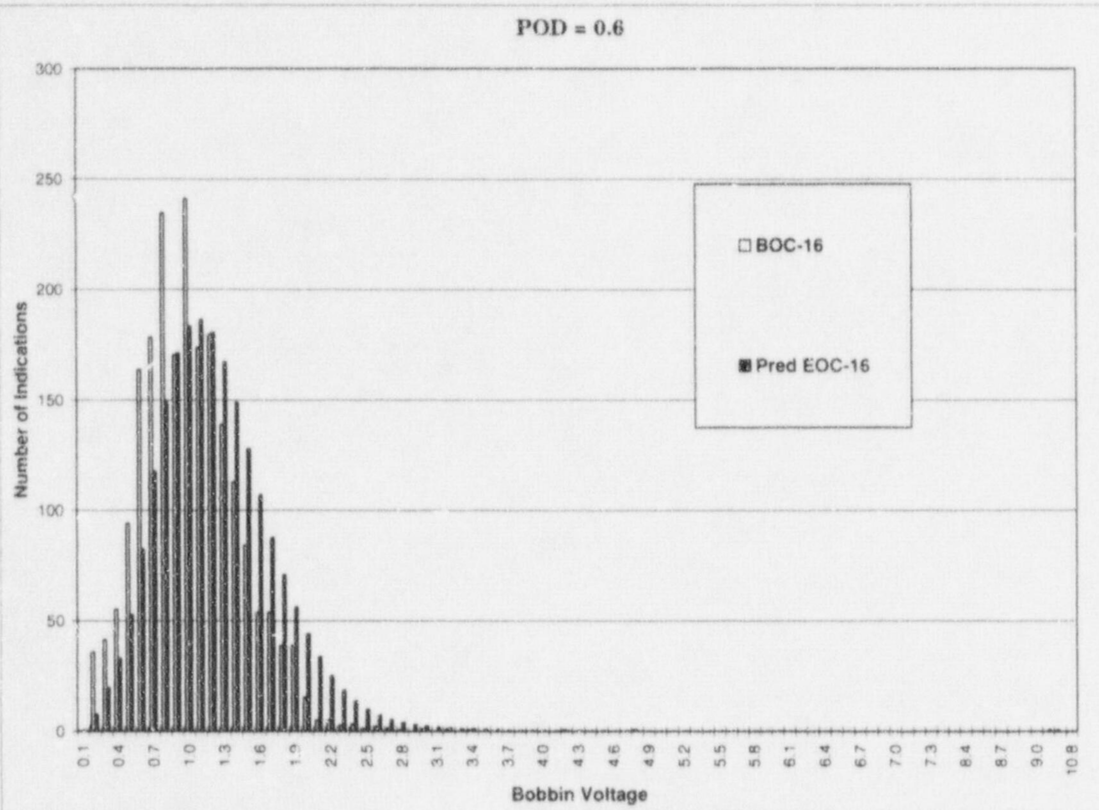


Figure 6-4
Farley Unit 1 SG-C
Predicted Bobbin Voltage Distribution for Cycle 16



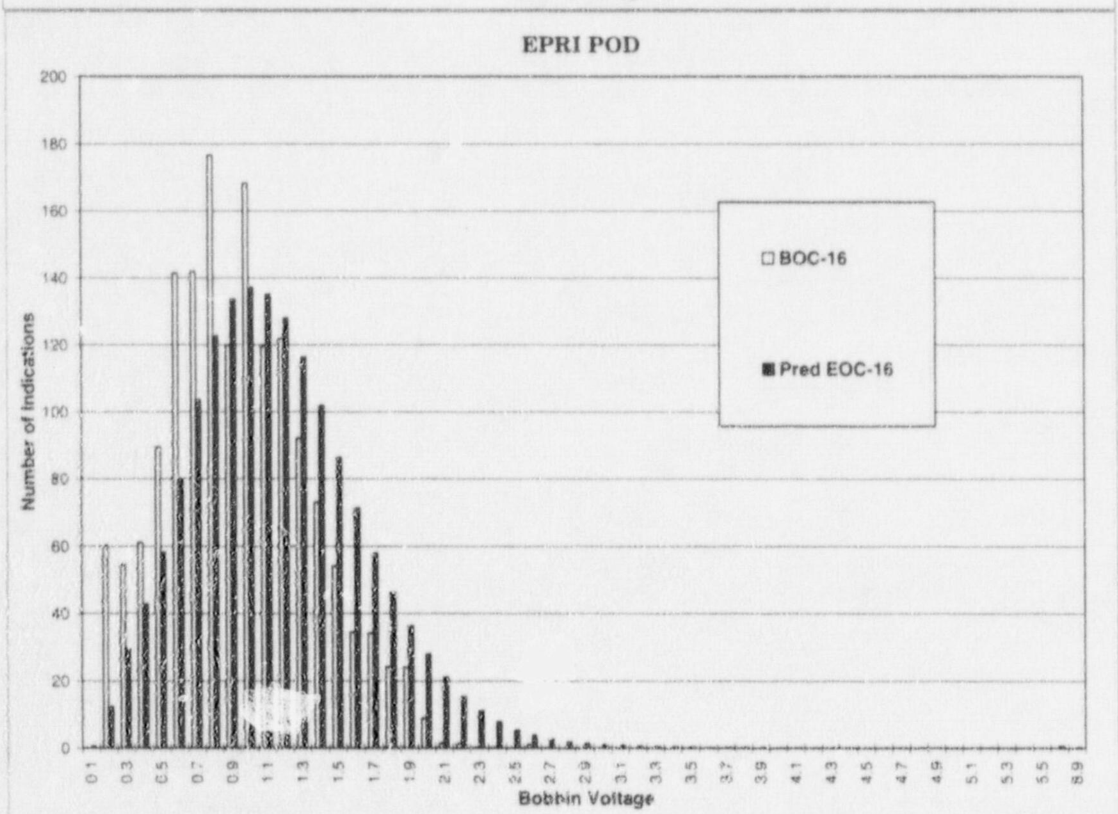
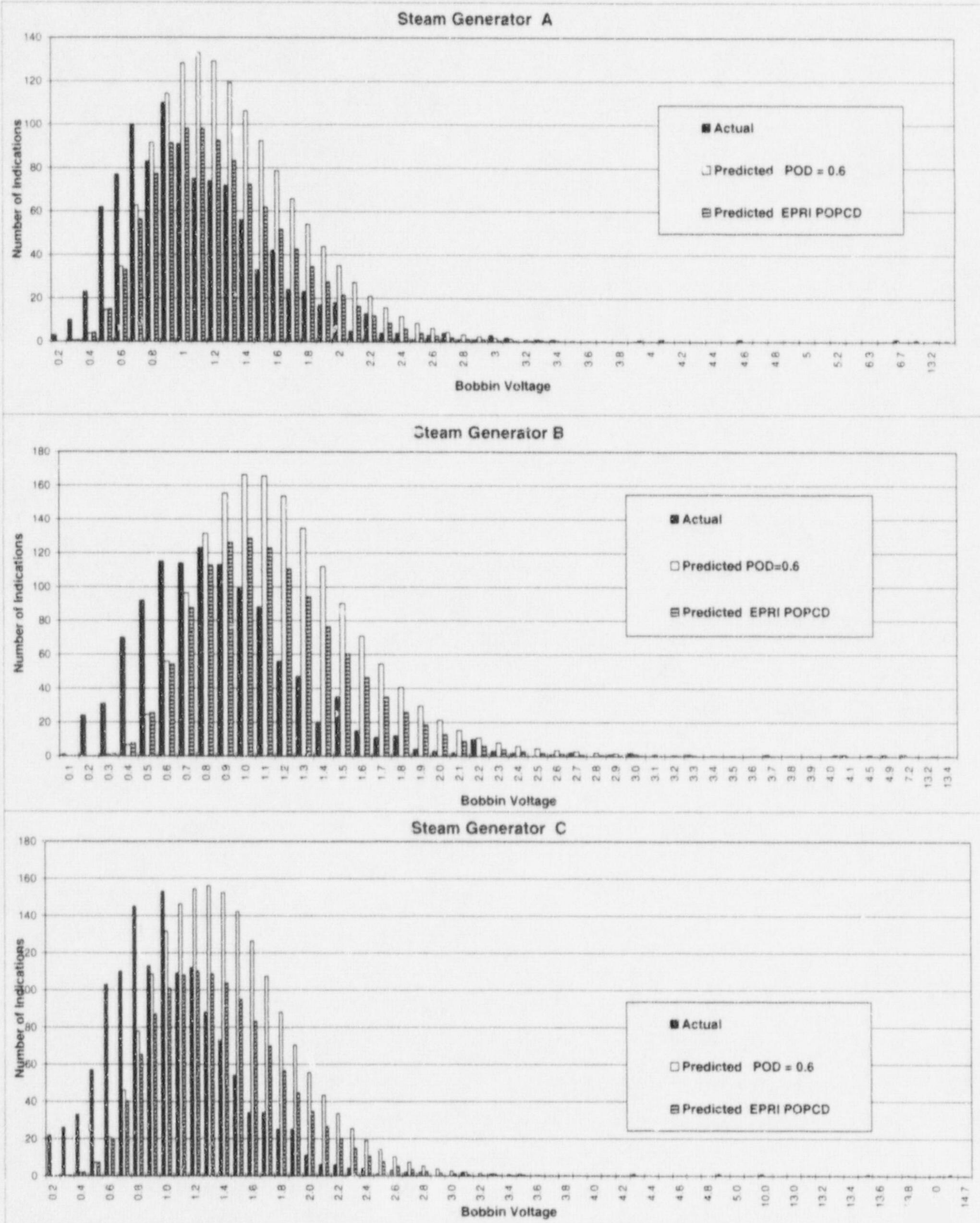


Figure 6-5
Farley Unit 1 November 1998
Bobbin Voltage Distributions for Cycle 15



7.0 TUBE LEAK RATE AND TUBE BURST PROBABILITIES

7.1 Calculation of Leak Rate and Tube Burst Probabilities

This section discusses tube leak and burst probability analyses using the voltage distributions projected for the end of the operating period. The calculation utilizes correlations relating bobbin voltage amplitudes (either measured or calculated) to free span burst pressure, probability of leakage and associated leak rates for ODSCC indications at TSP locations. The methodology used is documented in Reference 8.3, and is consistent with NRC criteria and guidelines of References 8.1. Leak rates based on the actual measured voltages are calculated using a leak rate correlation independent of voltage, and the leak rate calculations based on the projected EOC-16 voltages utilize the leak rate vs. bobbin voltage correlation shown in Section 4.0. The calculated leak rates are volumetric rates at room temperature and they should be with compared with allowable leak rates at room temperature.

The latest leak and burst correlations available at the time of the last Farley Unit-1 inspection (EOC-14) are documented in Reference 8.6. Since then, these correlations have been updated and the revised correlations are presented in the NRC approved Addendum-2 to the EPRI database report (Reference 8.7). Updated correlations are applied to project EOC-16 SLB leak rate and burst probability for all 3 SGs

7.2 Predicted and Actual Leak Rate and Tube Burst Probability for EOC-15

Analyses were performed to calculate SLB tube leak rate and burst probability for the actual bobbin voltage distribution at EOC-15. The results of Monte Carlo calculations performed based on the actual voltage distributions including NDE uncertainties are shown on Table 7-1. Projections for EOC-15 conditions for all three SGs presented in the last 90-day report are also included for comparison in Table 7-1. The allowable SLB rate for Farley-1 is 23.8 gpm (at room temperature).

Two sets of calculations are available for EOC-15 projections:

i) Calculations based on the original leak rate analysis method presented in Reference 8.3 for modeling a voltage-independent leak rate.

ii) An updated method that utilizes unbiased parameters for a leak rate distribution independent of voltage.

The SLB leak rate projections based on the unbiased leak rate parameters are more realistic, and they were chosen for comparison with the results calculated using the actual EOC-15 voltages.

Comparisons of the EOC-15 actuals with the corresponding predictions indicate the following:

a) SG-C was projected to be the limiting steam generator for EOC-15 based on EOC-14 data, and it was confirmed to be limiting based on the actual bobbin measurements for EOC-15. For all SGs, SLB leak rates based on the actual voltage distributions are less than those projected with POD =0.6 (by 45% to 115%) as well as POPCD (by 33% to 87%); they are also well below the acceptance limit (23.8 gpm at room temperature).

b) For all SGs, tube burst probabilities based on the actual voltage distributions are less than the projections with POD=0.6 as well as POPCD (by a factor of 2 to 5); they are also below the NRC reporting guideline of 10^{-2}.

c) SLB leak rate and burst probability for SG-C in Table 7-1 based on the more recent NRC approved database and correlations (Reference 8.7) also show similar margins between EOC-15 projections and actuals. The projected values are 2 to 4 times of those based on the actual measured voltages for SG-C.

In summary, the limiting SLB leak rate (3.8 gpm at room temperature) and tube burst probability (2.3×10^{-3}) calculated using the actual measured EOC-15 bobbin voltage distributions and the latest leak and burst database (including voltage-dependent leak rate correlation) that includes latest Farley pulled tube test data (Reference 8.7) are well below the corresponding allowable limits (23.8 gpm and 10^{-2}, respectively). The results meet the GL 95-05 requirement for continued operation.

7.3 Projected Leak Rate and Tube Burst Probability for EOC-16

Using the methodology previously described, calculations have been performed to predict the EOC-16 performance of all three steam generators in Farley Unit 1, and the results are summarized in Table 7-2. EOC-16 bobbin voltage distributions as well as the leak rates and tube burst probabilities based on those distributions are predicted. As mentioned earlier, EOC-16 leak rates and tube burst probabilities are calculated using the latest leak and burst correlations for 7/8" tubes presented in Reference 8.7. The projected leak rates are compared with the allowable leak rate at room temperature (23.8 gpm). The leak rate vs. bobbin voltage correlation shown in Section 4.0 is applied.

SG-C has both the highest number of indications as well as the largest indication returned to service for Cycle 16; therefore, it was projected to be the limiting SG. Since the growth rate for Cycle 15 is higher than that for Cycle 14, Cycle 15 growth data were used in the EOC-16 projection analysis. The predicted EOC-16 SLB leak rate and burst probability for all three SGs are shown in Table 7-2. The limiting EOC-16 SLB leak rate predicted for SG-C based on constant POD of 0.6 is 7.7 gpm (room temperature) which is well below the current licensed limit of 23.8 gpm at room temperature. The limiting EOC-16 burst probability (also predicted for SG-C with POD=0.6) is projected to be 3.1×10^{-3}; it is well below the NRC acceptance limit of 10^{-2}.

As discussed in Section 3.3, the Cycle 15 growth data show a slight dependency on the beginning of cycle voltage. Therefore, EOC-16 leak rate and tube burst probability were calculated using the method recommended in Reference 8.7 to account for voltage-dependent growth. The voltage-dependent growth distribution applied for SG-C was obtained using its own growth data plus the largest growth in SGs A and B. The EOC-16 leak rate and burst probability values obtained using voltage-dependent growth are slightly higher than those obtained using the conventional method presented in Reference 8.3 (by 0.5 gpm and 2.5×10^{-3}, respectively), and they are still well below the corresponding allowable limits for Farley Unit-1. Thus, the projected EOC-16 results meet the GL 95-05 requirements for continued operation.

In summary, SLB leak rates and tube burst probabilities projected for EOC-16 for all three SGs using the NRC-mandated POD = 0.6 meet the SER limits for Farley Unit-1. Results based on voltage dependent POPCD show even a greater margin between EOC-16 predictions and acceptance limits.

Table 7-1
Farley Unit 1 1998 EOC-15 Outage
Summary of Calculations of Tube Leak Rate and Burst Probability

Steam	POD	Number of Indications(1)	Max. Volts	Burst Probability		SLB Leak Rate (gpm)(4)
				1 Tube	1 or More Tubes	
EOC - 15 PROJECTIONS(2) (Leak Rate Correlation Not Used -- Unbiased Leak Rate Parameters)						
A	0.6	1416.3	13.5	2.5×10^{-3}	2.5×10^{-3}	7.9
B		1570.0	13.4	2.2×10^{-3}	2.2×10^{-3}	6.9
C		1766.0	14.7	9.9×10^{-3}	9.9×10^{-3}	11.4
A	POPCD	1019.1	13.2	1.5×10^{-3}	1.5×10^{-3}	6.8
B		1175.1	13.2	1.6×10^{-3}	1.6×10^{-3}	6.1
C		1231.5	14.0	4.6×10^{-3}	4.7×10^{-3}	9.9
Addendum 2 (Reference 8.7) Leak Rate Correlation Applied						
C(3)	0.6	1766.0	14.7	1.0×10^{-2}	1.0×10^{-2}	8.3
EOC - 15 ACTUALS (Same Leak and Burst Database as Used in the Above Projections– Leak Rate Correlation Not Used)						
A	1	1039	6.7	7.5×10^{-4}	7.6×10^{-4}	4.7
B		1101	7.2	7.3×10^{-4}	7.3×10^{-4}	3.4
C		1362	10.2	2.1×10^{-3}	2.1×10^{-3}	5.3
C(3)	1	1362	10.2	2.2×10^{-3}	2.3×10^{-3}	3.8

Notes: (1) Adjusted for POD.

(2) Based on a Projected Cycle 15 length of 485.8 EFPD (vs. actual 471.2 EFPD).

(3) Latest leak and burst database and correlations, including leak rate correlation, in Reference 8.7, applied (includes French data in the PoL correlation).

(4) Volumetric leak rate adjusted to room temperature.

Table 7-2
Farley Unit-1
Summary of Projected Tube Leak Rate and Burst Probability for EOC-16
(Based on a projected Cycle 16 length 420 EFPD or 1.15 EFPY)

Steam Generator	POD	No. of Indications[1]	Max. Volts	Burst Probability		SLB Leak Rate (gpm)[2]	Comments
				1 Tube	One or More Tubes		
Leak and Burst Database and Correlations Reported in Reference 8.7 Applied							
A[3]	0.6	1[illegible]24.7	9.6	2.9×10^{-3}	2.9×10^{-3}	6.7	Leak rate Correlation applied
B[4]		1744.0	9.0	1.5×10^{-3}	1.5×10^{-3}	5.1	
C[4]		2129.0	10.8	3.1×10^{-3}	3.1×10^{-3}	7.7	
C[5]		1362	11.0	5.6×10^{-3}	5.6×10^{-3}	8.2	
A[3]	POPCD	1194.0	9.4	1.8×10^{-3}	1.8×10^{-3}	4.3	
B[4]		1413.0	8.7	6.5×10^{-4}	6.5×10^{-4}	3.5	
C[4]		1603.1	8.9	1.0×10^{-3}	1.0×10^{-3}	5.1	

Notes

(1) Number of indications adjusted for POD.
(2) Volumetric leak rate adjusted to room temperature.
(3) A growth rate distribution composed of SG-A specific data plus the largest growth in SG-B and SG-C applied.
(4) All SG composite growth rate distribution applied.
(5) A SG-C specific voltage-dependent growth distribution that includes top 3 growths observed for Cycle 15 applied.

8.0 REFERENCES

8.1 NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking", USNRC Office of Nuclear Reactor Regulation, August 3, 1995.

8.2 Safety Evaluation Report, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 128 to Facility Operating License NPF-8, Southern Nuclear Operating Company, Inc., Joseph M. Farley Nuclear Station, Unit 1, Docket No. 50-348", United States Nuclear Regulatory Commission, May 19,1997.

8.3 WCAP-14277, Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections," Westinghouse Nuclear Services Division, December 1996.

8.4 SG-97-08-004, "Farley Unit-1 1997 Alternate Repair Criteria 90 Day Report," Westinghouse Nuclear Services Division, August 1997.

8.5 SG-96-01-003, "Farley Unit-1, 1995 Interim Plugging Criteria 90 Day Report," Westinghouse Electric Corporation, January 1996.

8.6 NSD-SGD-1212, "EPRI ARC Databases for 3/4" and 7/8" Dia. Tubes and Updated ARC Correlation for 7/8" Dia. Tubes," Westinghouse memorandum dated February 26, 1996 transmitted to Duquesne Light Company and Tennessee Valley Authority.

8.7 Addendum-2 to EPRI Report NP-7480-L, "Steam Generator Outside Diameter Stress Corrosion Cracking at Tube Support Plates - Database for Alternate Repair Criteria," April 1998.

8.8 Letter from B. W. Sheron, Nuclear Regulatory Commission, to A. Marion, Nuclear Energy Institute, dated February 9, 1996.

8.8 Letter from R. Clive Callaway, Nuclear Energy Research Institute, to Nuclear Regulatory Commission, "Updated ODSCC ARC Correlations for 7/8" Diameter Tubes," dated December 29, 1997.

8.9 Letter from G. C. Lainas, Nuclear Regulatory Commission, to D. J. Modeen, Nuclear Energy Institute, "Evaluation of Proposed Update to SGDSM Database and Modifications to the Methodology to Assess Steam Generator Tubing Outside Diameter Stress Corrosion Cracking," dated November 20, 1998.