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FARLEY UNIT-2

CYCLE 14 VOLTAGE-BASED REPAIR CRITERIA 90-DAY REPORT

February 2000

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TABLE OF CONTENTS

FARLEY UNIT-2

Cycle 14 VOLTAGE-BASED REPAIR CRITERIA 90 DAY-REPORT

1.0 INTRODUCTION

This report provides the Farley Unit-2 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 14 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 14 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 90-day reports for Farley Unit-2 (References 8-4 through 8-7).

Eddy current and repair data for TSP indications are provided in Section 3. No tubes were deplugged during the EOC-13 outage with the intention of returning them to service after inspection. The actual EOC-13 voltage distributions as well as leak rates and tube burst probabilities calculated for these distributions are compared with the projections for EOC-13 conditions performed using the EOC-12 data. Leak rates and burst probabilities for the projected EOC-14 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 EOC-13 voltage distributions and the results compared with the projections performed after the last outage. The total number of indications found at TSP intersections in each SG during the current inspection and the actual peak voltages are less than those projected at the beginning of the cycle per the Generic Letter 95-05 requirements using a constant POD of 0.6. With alternate EOC-13 projections based on the voltage-dependent POPCD, the total number of indications is overestimated for SG-C, within one indication for SG-A and underestimated for SG-B (by about 10%). However, EOC-13 peak voltages are overpredicted for all three SGs with POPCD. The leak rates and tube burst probabilities calculated using the actual measured voltages are below those projected with both a constant POD of 0.6 as well as voltage-dependent POPCD. SG-C was predicted to be the limiting SG at EOC-13 and was found limiting based on the actual measured EOC-13 voltage data.

For the actual EOC-13 bobbin voltage distribution, the largest SLB leak rate is calculated for SG-C, and its magnitude is 1.1 gpm. The projected leak rate values were 2.0 gpm with POD=0.6 and 1.4 gpm with POPCD. Leak rates for the actual EOC-13 conditions were obtained using the leak rate vs. bobbin voltage correlation based on the latest leak and burst database for 7/8" tubes. The above limiting leak rate value is only about a tenth of the current allowable SLB leakage limit of 11.8 gpm. All leak rate values quoted are equivalent volumetric rates at room temperature. The corresponding conditional tube burst probability based on the actual SG-C voltage data is 3.0×10-4, and it is well within the NRC reporting guideline of 10-2. The predicted values were 5.6×10-4 for POD=0.6 and 3.7×10-4 for POPCD. Thus, the results show that the projections based on voltage-dependent POD (POPCD) provide more realistic but still conservative estimates for leak rate and burst probability.

SG-C is again predicted to be the limiting SG since it had more indications than the other two SGs combined at EOC-13 and also had nearly twice the number of indications over 2 volts (not confirmed by a Rotating Pancake Coil [RPC] probe) returned to service as the other two SGs combined. Using the NRC mandated constant POD of 0.6 and the latest leak and burst database for 7/8" tubes (EPRI database Addendum 3, Reference 8-8), the limiting EOC-14 SLB leak rate for SG-C is projected to be 2.2 gpm (room temperature), which is less than 1/5th of the current licensed limit of 11.8 gpm (room temperature). The corresponding tube burst probability for SG-C is 4.4×10-4, and it is substantially below the NRC reporting guideline of 10- 2. Thus, the GL 95-05 requirements for continued plant operations are met.

A total of 652 indications were found in the EOC-13 inspection, of which 48 are over 2 volts. All indications over 2 volts plus 8 indications under 2 volts were inspected with a RPC probe, and only 17 were confirmed as flaws (12 over 2 volts and 5 under 2 volts). The largest number of bobbin indications over 2 volts not confirmed by RPC, 23 indications, were in SG-C, and they all would be returned to service for Cycle 14 operation. No circumferential indications, axial indications extending outside the TSP, PWSCC, volumetric signals, or copper-type signals were identified by RPC inspection at TSP intersections. Four axial TSP ODSCC indications were detected during RPC inspection of TSP residual signals, and they were all in SG-C. RPC inspection of support plate residuals was expanded to 192 more intersections in SG-C, but no other TSP ODSCC indication was found. The tubes in SG-C containing the above 4 indications were repaired.

3.0 EOC-13 INSPECTION RESULTS AND VOLTAGE GROWTH RATES

3.1 EOC-13 Inspection Results

In accordance with the guidance provided by the NRC generic letter (Reference 8-1), the EOC-13 inspection of the Farley Unit-2 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 the 2-volt repair criteria was applied. Subsequently, RPC examination was performed for all bobbin indications with amplitudes greater than 2 volts in all three SGs. Forty-eight indications were found above 2 volts in all SGs combined; they were all inspected with RPC, and only 12 of them were confirmed as flaws and removed from service.

An augmented RPC inspection was performed consistent with the NRC requirements. All dented intersections with a bobbin voltage greater than 5 volts were inspected with a RPC probe and no ID or OD indications were detected. Large bobbin residual artifact signals were also RPC inspected. Four axial TSP ODSCC indications were detected during RPC inspection of TSP residual signals, and they were all in SG-C. Therefore, RPC inspection of support plate residuals was expanded to 192 more intersections in SG-C, but no other ODSCC indication was found. The tubes in SG-C containing the above 4 indications were repaired. No circumferential indications, axial indications extending outside the TSP, PWSCC, volumetric signals or copper-type signals were identified by RPC inspection at TSP intersections.

A summary of eddy current (EC) voltage distributions for all steam generators is shown on Table 3-1, which tabulates the number of field bobbin indications, the number of these field bobbin indications that were RPC inspected, 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 14 operation is the difference between the observed and the ones removed from service. No tubes were deplugged in the current inspection with the intent of returning them to service after inspection.

Overall, the combined data for the Farley Unit-2 steam generators show the following:

- A total of 652 bobbin signals were identified as TSP indications during the inspection, and they were all called as PIs.

- Of the 652 PIs, 287 were above 1 volt and 48 exceeded 2 volts.

- A total of 56 indications (of which 48 were over 2 volts) were RPC inspected, and only 17 (of which 12 were over 2 volts) were confirmed. Thirty-five out of 36 indications over 2 volts not confirmed by RPC were returned to service.

- Of the 34 indications removed from service, only 12 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 304, with 157 indications above 1.0 volt) will be returned to service in SG-C, almost as many indications as in the other 2 SGs combined, including 23 out of a total of 48 indications over 2 volts found in this inspection. Clearly, SG-C will be the limiting SG at EOC-14.

Figure 3-1 shows the actual bobbin voltage distribution for tubes that were in service during Cycle 13, as determined from the EOC-13 EC inspection. Figure 3-2 shows the distribution of the EOC-13 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-13.

The distribution of EOC-13 indications as a function of support plate elevation, summarized in Table 3-2 and illustrated on Figure 3-4. The data show that more indications occurred at the bottom 2 TSPs on the hot leg side than at any other TSP intersection, similar to that observed at other plants, indicating predominant temperature dependency of ODSCC indication. However, during the past 3 cycles, the number of indications at the top 3 TSPs on the hot leg side and the total number of indications on the cold leg side appear to be increasing faster than at the bottom 3 TSPs, as seen in the table below.

Inspection	Bottom 3 TSPs (HL)		Top 3 TSPs (HL)		All CL Indications	
	No. of Inds.	Percent of Total	No. of Inds.	Percent of Total	No. of Inds.	Percent of Total
EOC-13	298	46%	184	28%	153	23%
EOC-12	257	51%	140	28%	97	19%
EOC-11	257	63%	94	23%	46	11%

3.2 Voltage Growth Rates

For projection of leak rates and tube burst probabilities at the end of Cycle 14 operation, voltage growth rates were developed from EOC-13 inspection data and a reevaluation of the same indications from the EOC-12 inspection EC signals. Table 3-3 shows the average growth rate for each SG during Cycle 13. SG-C has a slightly larger average growth rate as well as the indication with the largest growth rate for the cycle (1.8 volts/EFPY). Average growth rates observed for all voltages vary between 3.2% and 6.0%, between SGs, with an overall average of 5.0%, on an EFPY basis. The average growth rate for indications with a BOC bobbin voltage above 0.75 volt is 3.9% per EFPY and for indications below 0.75 volt it is 9.3% per EFPY. The magnitude of the actual voltage growth is small for both indications below and above 0.75 volts and the differences are insignificant. Table 3-4 provides a comparison of average growth data for the last 8 operating cycles, and the data generally show a steady reduction in the average growth rates. The downward trend in the growth data since 1990 has continued.

The bobbin voltage growth distributions for the last two cycles in the form of cumulative probability distribution functions (CPDF) are shown in Table 3-5, and the same data is presented in a graphical form on Figures 3-5 and 3-6. These growth data are presented on an EFPY basis to account for the difference in the length of the two operating periods. The data in Figure 3-6 show that the growth distributions for Cycles 12 and 13 are close to each other. However, since the top growth value for Cycle 13 is nearly twice as large as the largest Cycle 12 growth, the Cycle 13 growth distribution is more limiting and was applied to obtain EOC-14 projections. Also, as evident in Table 3-5 and Figure 3-5, the Cycle 13 growth distribution for SG-C is more limiting than the composite distribution.

Some plants with 3/4" tube SGs have experienced growth rates that are dependent on the beginning of cycle (BOC) voltage. To determine if Farley Unit-2 exhibited a similar trend during Cycle 13, growth data for Cycle 13 were plotted against BOC voltage, and the resulting plot is shown in Figure 3-7. One indication in SG-C with a BOC-13 voltage of about 2 volts had large growth (2.3 volts), but another indication in SG-B with a BOC-13 voltage of about 2.2 volts shows a large negative growth (-1.6 volts). With the exception of these two indications, the Cycle 13 growth values show nearly a uniform distribution relative to BOC-13 voltage, with about 98% of growth values being within ±0.5 volts. Thus, Cycle 13 growth is taken to be independent of BOC voltage.

Table 3-6 lists the top 30 indications from the standpoint of growth during Cycle 13, and the data show that the growth rate during Cycle 13 was moderate. With the exception of one indication in SG-C, voltage growth during Cycle 13 was under 1 volt for all indications. Of the 30 indications, 10 were confirmed by RPC Inspection and only 5 were identified as being new for Cycle 13.

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. As noted earlier, Cycle 13 growth rates were used to perform EOC-14 projections as they are slightly higher than the Cycle 12 growth rates. Since the Cycle 13 growth rates for SGs A and B are below the composite growth rate (see Table 3-5 and Figure 3-5), the composite growth rate is applied to these two SGs to provide a conservative basis for predicting EOC-14 conditions. However, predictions for SG-C are obtained using its own growth rate since it is higher than the composite rate.

3.3 Probe Wear Criteria

An alternate probe wear criterion discussed in Reference 8-10 was applied during the EOC-13 inspection. When a probe does not pass the 15% wear limit, this alternate criteria requires 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 indications for which the worn probe voltage was 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 8-10, 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 any significant indications. Figure 3-8 shows plots of the worn probe voltages plotted against the new probe voltages for all three SGs. There was only one indication needing retesting in SG-A and only 5 in SG-B, so the data for those two SGs are combined. The data in Figure 3-8 show a consistent relationship between the two voltages. However, two indications in SG-C had a worn probe voltage about 3 times the new probe voltage, another 2 indications had worn probe voltages about 50% to 60% of the new probe voltages. The latter two indications did not require retesting (because their worn probe voltages are below 1.5 volts), and their voltage data are within the 90%/95% tolerance limit bands and hence acceptable.

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 a slope of about 1.0 indicating that, on the average, worn probe voltages are comparable to 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 tube requiring repair may be left in service because of probe wear. In the Farley-2 EOC-13 inspection, there are no occurrences for which a worn probe was less than 1.5 volts and the new probe voltage exceeded the plugging limit, i.e., no pluggable tubes were missed due to probe wear considerations. Among the indications requiring retesting (worn probe volts > 1.5 volts), 2 indications fall outside the band formed by the chained lines representing ±25% of the new probe voltage as well as the 90%/95% tolerance limit bands. However, the worn probe voltages for these 2 indications are higher than the corresponding new probe voltages, i.e., the worn probe voltages are conservative, and therefore the data for these indications are acceptable.

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-13 inspection is consistent with the NRC guidance provided in Reference 8-10.

3.4 Probability of Prior Cycle Detection (POPCD)

The inspection results at EOC-13 permit an evaluation of the probability of detection (POD) at the prior EOC-12 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-12 inspection can then be defined as follows.

	EOC-12 cycle reported indications confirmed by RPC in EOC-13 inspection	+	Indications confirmed and repaired in EOC-12 inspection
POPCD = (EOC-12)	{Numerator}	+	New indications RPC confirmed in EOC-13 inspection

POPCD is evaluated at the 1998 EOC-12 voltage values (from 1999 reevaluation for growth rate) since it is an EOC-12 POPCD assessment. The indications at EOC-12 that were RPC confirmed and plugged are included as it can be expected that these indications would also have been detected and confirmed at EOC-13. 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-13 indications not reported in the EOC-12 inspection. The new indications include EOC-12 indications present at detectable levels but not reported, indications present at EOC-12 below detectable levels and indications that initiated during Cycle 13. Thus, this definition, by including newly initiated indications, differs from the traditional POD definition. Since the newly initiated indications are appropriate for ARC 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-13 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 1999 EOC-13 indications not RPC inspected since inclusion of the EOC-12 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-13 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-2.

The POPCD evaluation for the 1998 EOC-12 inspection data is summarized in Table 3-7 and illustrated on Figure 3-10. Since data for RPC confirmed only indications is sparse, although all confirmed indications were reported at EOC-12, only data for RPC confirmed plus not RPC inspected indications are shown in Figure 3-10. Also shown in the figure is a generic POPCD distribution developed by analyses of 18 inspections in 10 plants and presented in Table 7-4 of Reference 8-9. It is seen from Figure 3-10 that the predicted POPCD values for Farley-2 are equal to or better than the generic POPCD between 0.2 volt and 0.8 volt. POPCD for Farley-2 remains at about 0.8 beyond 0.8 volt and reaches unity at about 2 volts.

In summary, the Farley Unit-2 EOC-12 POPCD supports a voltage dependent POD higher than the NRC mandated POD value of 0.6 above about 0.5 volt and approaching unity at about 2 volts. It is concluded that the POD applied for leak and burst projections to support a voltage-based repair criteria needs to be upgraded from the constant POD value of 0.6 to a voltage dependent POD.

3.5 Assessment of RPC Confirmation Rates

This section tracks the 1998 EOC-12 indications left in service at BOC-13 relative to RPC inspection results in 1999 at EOC-13. The composite results for all SGs are given in Table 3-8. For EOC-12 bobbin indications left in service, the indications are tracked relative to EOC-12 RPC confirmed, EOC-12 RPC NDD, EOC-12 bobbin indications not RPC inspected and EOC-12 bobbin indications not found in the EOC-13 inspection. Also included are new Cycle 13 indications. The table shows, for each category of indications, the number of indications RPC inspected and RPC confirmed in the EOC-13 inspection as well as the percentage of RPC confirmed indications.

Twenty-five of the 27 RPC NDD indications left in service at BOC-13 were RPC tested during the EOC-13 inspection, and none were confirmed. Therefore, the confirmation rate for EOC-12 RPC NDD indications 0%. This result is consistent with similar evaluations carried out after the EOC-10, EOC-11 and EOC-12 outages that showed that none of the 29 prior cycle RPC NDD indications RPC tested were confirmed. 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. The fractional value appropriate for voltage-based repair criteria 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 < 50% of RPC NDD indications for projecting EOC voltage distributions for Farley Unit-2. However, since NRC approval has not been obtained, leak and burst analyses presented in this report are based on 100% of RPC NDD indications.

3.6 NDE Uncertainties

The NDE uncertainties applied for the EOC-13 voltage projections in this report are those given in the prior Farley Unit-2 90-day reports (References 8-4 through 8-7). 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 8.3% about a mean of zero with no cutoff. These NDE uncertainty distributions are included in the Monte Carlo analyses used to project the EOC-13 voltage distributions.

Table 3-1 (Sheet 1 of 2)
Farley Unit 2 November 99 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 12

Voltage Bin	Steam Generator A						Steam Generator B					
	In-Service During Cycle 12				RTS for Cycle 13		In-Service During Cycle 12				RTS for Cycle 13	
	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
0.2	2	0	0	0	2	2	0	0	0	0	0	0
0.3	0	0	0	0	0	0	7	0	0	0	7	7
0.4	4	0	0	0	4	4	14	0	0	0	14	14
0.5	18	1	0	0	18	17	33	0	0	2	31	31
0.6	11	1	1	1	10	10	22	0	0	0	22	22
0.7	11	0	0	0	11	11	16	0	0	0	16	16
0.8	7	0	0	0	7	7	20	0	0	0	20	20
0.9	11	0	0	0	11	11	15	0	0	0	15	15
1	2	0	0	0	2	2	13	0	0	0	13	13
1.1	3	1	1	0	3	3	15	0	0	0	15	15
1.2	4	1	0	0	4	3	8	0	0	1	7	7
1.3	9	0	0	0	9	9	10	0	0	0	10	10
1.4	4	0	0	0	4	4	8	0	0	0	8	8
1.5	6	0	0	0	6	6	6	0	0	0	6	6
1.6	1	0	0	0	1	1	5	0	0	0	5	5
1.7	4	0	0	0	4	4	4	0	0	0	4	4
1.8	2	0	0	0	2	2	2	0	0	0	2	2
1.9	1	0	0	0	1	1	4	0	0	0	4	4
2	0	0	0	0	0	0	4	0	0	0	4	4
2.1	2	2	1	2	0	0	2	2	0	0	2	0
2.2	1	1	0	0	1	0	2	2	0	0	2	0
2.3	0	0	0	0	0	0	1	1	0	0	1	0
2.4	1	1	0	0	1	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	1	1	0	0	1	0
2.6	1	1	0	0	1	0	0	0	0	0	0	0
2.7	0	0	0	0	0	0	1	1	0	0	1	0
2.8	0	0	0	0	0	0	1	1	0	0	1	0
2.9	0	0	0	0	0	0	0	0	0	0	0	0
3.2	0	0	0	0	0	0	0	0	0	0	0	0
3.3	0	0	0	0	0	0	1	1	0	0	1	0
3.4	0	0	0	0	0	0	0	0	0	0	0	0
4.3	0	0	0	0	0	0	0	0	0	0	0	0
Total	105	9	3	3	102	97	215	9	0	3	212	203
>1v	39	7	2	2	37	33	75	9	0	1	74	65
>2v	5	5	1	2	3	0	9	9	0	0	9	0

Table 3-1 (Sheet 2 of 2)
Farley Unit 2 November 99 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 12

Voltage Bin	Steam Generator C						Composite of All SGs					
	In-Service During Cycle 12				RTS for Cycle 13		In-Service During Cycle 12				RTS for Cycle 13	
	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
0.2	0	0	0	0	0	0	2	0	0	0	2	2
0.3	4	0	0	0	4	4	11	0	0	0	11	11
0.4	8	0	0	0	8	8	26	0	0	0	26	26
0.5	19	2	2	2	17	17	70	3	2	4	66	65
0.6	34	0	0	1	33	33	67	1	1	2	65	65
0.7	26	1	0	1	25	24	53	1	0	1	52	51
0.8	29	1	1	4	25	25	56	1	1	4	52	52
0.9	20	0	0	2	18	18	46	0	0	2	44	44
1	19	0	0	2	17	17	34	0	0	2	32	32
1.1	15	0	0	1	14	14	33	1	1	1	32	32
1.2	20	0	0	1	19	19	32	1	0	2	30	29
1.3	21	0	0	0	21	21	40	0	0	0	40	40
1.4	15	0	0	0	15	15	27	0	0	0	27	27
1.5	17	0	0	0	17	17	29	0	0	0	29	29
1.6	11	0	0	0	11	11	17	0	0	0	17	17
1.7	12	0	0	1	11	11	20	0	0	1	19	19
1.8	8	0	0	0	8	8	12	0	0	0	12	12
1.9	10	0	0	2	8	8	15	0	0	2	13	13
2	10	0	0	0	10	10	14	0	0	0	14	14
2.1	5	5	2	2	3	0	9	9	3	4	5	0
2.2	5	5	2	2	3	0	8	8	2	2	6	0
2.3	6	6	2	2	4	0	7	7	2	2	5	0
2.4	1	1	0	0	1	0	2	2	0	0	2	0
2.5	5	5	1	1	4	0	6	6	1	1	5	0
2.6	1	1	0	0	1	0	2	2	0	0	2	0
2.7	3	3	2	2	1	0	4	4	2	2	2	0
2.8	3	3	0	0	3	0	4	4	0	0	4	0
2.9	1	1	0	0	1	0	1	1	0	0	1	0
3.2	1	1	0	0	1	0	1	1	0	0	1	0
3.3	0	0	0	0	0	0	1	1	0	0	1	0
3.4	1	1	0	0	1	0	1	1	0	0	1	0
4.3	2	2	2	2	0	0	2	2	2	2	0	0
Total	332	38	14	28	304	280	652	56	17	34	618	580
>1v	173	34	11	16	157	134	287	50	13	19	268	232
>2v	34	34	11	11	23	0	48	48	12	13	35	0

Table 3-2
Farley Unit 2 October 1999
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 13

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	31	2.08	0.98	0.30	0.07	40	1.53	0.79	0.45	0.00
2H	20	1.71	0.87	0.46	0.07	27	2.61	0.81	0.86	0.06
3H	4	1.27	0.97	0.19	0.10	11	2.06	1.18	0.17	0.05
4H	2	0.68	0.58	0.31	0.17	3	0.78	0.63	0.16	0.07
5H	10	2.58	1.29	0.22	0.03	17	1.58	1.05	0.82	0.07
6H	12	2.37	1.08	0.27	0.10	12	2.16	0.79	0.16	0.05
7H	7	1.86	1.01	0.39	-0.02	35	1.84	0.74	0.54	0.01
7C	0	-	-	-	-	42	1.81	0.88	0.37	0.06
6C	2	0.49	0.35	0.00	-0.02	11	3.26	1.78	0.24	0.11
5C	11	1.28	0.73	0.17	0.00	7	2.14	1.39	0.40	0.11
4C	0	-	-	-	-	0	-	-	-	-
3C	3	1.21	0.86	0.25	0.10	5	2.76	1.25	0.11	0.02
2C	3	0.65	0.56	0.09	0.06	2	1.06	0.95	0.03	0.02
1C	0	-	-	-	-	3	0.63	0.47	0.06	-0.51
Total	105					215				

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	113	4.30	1.09	0.96	0.12	184	4.30	1.01	0.96	0.09
2H	38	4.25	0.99	2.30	0.12	85	4.25	0.90	2.30	0.09
3H	13	2.72	0.98	0.29	0.00	28	2.72	1.05	0.29	0.03
4H	13	1.99	0.89	0.39	0.13	18	1.99	0.81	0.39	0.12
5H	24	2.78	1.50	0.33	0.03	51	2.78	1.31	0.82	0.04
6H	39	3.37	1.35	0.25	0.06	63	3.37	1.19	0.27	0.06
7H	28	2.24	1.21	0.33	0.11	70	2.24	0.96	0.54	0.05
7C	19	1.72	1.16	0.27	-0.02	61	1.81	0.97	0.37	0.04
6C	12	2.86	1.62	0.16	0.06	25	3.26	1.59	0.24	0.07
5C	16	3.14	1.51	0.15	0.00	34	3.14	1.23	0.40	0.02
4C	1	0.99	0.99	0.08	0.08	1	0.99	0.99	0.08	0.08
3C	4	1.37	1.08	0.25	0.18	12	2.76	1.09	0.25	0.09
2C	6	2.16	1.29	0.24	0.08	11	2.16	1.03	0.24	0.06
1C	6	1.19	0.82	0.13	0.03	9	1.19	0.70	0.13	-0.15
Total	332					652				

Table 3-3
Farley Unit 2 - October 1999 Outage
Average Voltage Growth During Cycle 13

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	652	0.99	0.065	0.050	6.5%	5.0%
V_{BOC} < .75 Volts	273	0.51	0.061	0.047	12.1%	9.3%
≥ .75 Volts	379	1.34	0.067	0.052	5.0%	3.9%
	Steam Generator A					
Entire Voltage Range	105	0.88	0.060	0.046	6.8%	5.2%
V_{BOC} < .75 Volts	53	0.50	0.066	0.051	13.1%	10.1%
≥ .75 Volts	52	1.26	0.053	0.041	4.2%	3.3%
	Steam Generator B					
Entire Voltage Range	215	0.88	0.036	0.028	4.1%	3.2%
V_{BOC} < .75 Volts	102	0.49	0.040	0.031	8.3%	6.4%
≥ .75 Volts	113	1.24	0.032	0.025	2.6%	2.0%
	Steam Generator C					
Entire Voltage Range	332	1.09	0.084	0.065	7.7%	6.0%
V_{BOC} < .75 Volts	118	0.53	0.077	0.059	14.6%	11.3%
≥ .75 Volts	214	1.40	0.089	0.068	6.3%	4.9%

Based on Cycle 13 duration of 473 EFPD (1.295 EFPY)

Table 3-4
Farley Unit 2 October 1999
Average Voltage Growth Statistics
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 13 (1998 - 1999) - 473 EFPD					
Entire Voltage Range	652	0.99	0.065	0.050	6.5%	5.0%
V_{BOC} < .75 Volts	273	0.51	0.061	0.047	12.1%	9.3%
≥ .75 Volts	379	1.34	0.067	0.052	5.0%	3.9%
	Cycle 12 (1996 - 1998) - 460 EFPD					
Entire Voltage Range	507	0.96	0.070	0.056	7.3%	5.8%
V_{BOC} < .75 Volts	224	0.53	0.053	0.042	9.9%	7.9%
≥ .75 Volts	283	1.31	0.084	0.066	6.4%	5.1%
	Cycle 11 (1995 - 1996) - 477 EFPD					
Entire Voltage Range	411	0.92	0.083	0.063	9.0%	6.9%
V_{BOC} < .75 Volts	187	0.53	0.017	0.013	3.1%	2.4%
≥ .75 Volts	224	1.24	0.138	0.106	11.2%	8.5%
	Cycle 10 (1993 - 1995) - 444 EFPD					
Entire Voltage Range	197	0.79	0.010	0.008	1.2%	1.0%
V_{BOC} < .75 Volts	122	0.55	0.02	0.016	3.6%	3.0%
≥ .75 Volts	75	1.18	-0.007	-0.006	-0.6%	-0.5%
	Cycle 9 (1992 - 1993) - 462 EFPD					
Entire Voltage Range	169	0.76	0.090	0.071	11.8%	9.4%
V_{BOC} < .75 Volts	105	0.51	0.10	0.079	19.6%	15.5%
≥ .75 Volts	64	1.18	0.090	0.071	7.6%	6.0%
	Cycle 8 (1990 - 1992) - 405 EFPD					
Entire Voltage Range	308	0.73	0.140	0.126	19.2%	17.3%
V_{BOC} < .75 Volts	233	0.57	0.17	0.153	29.8%	26.9%
≥ .75 Volts	75	1.23	0.040	0.036	3.3%	2.9%
	Cycle 7 (1989 - 1990) - 468 EFPD					
Entire Voltage Range	326	0.71	0.110	0.086	15.5%	12.1%
V_{BOC} < .75 Volts	207	0.52	0.16	0.125	30.8%	24.0%
≥ .75 Volts	119	1.04	-0.120	-0.094	-11.5%	-9.0%
	Cycle 6 (1987 - 1989) - 462 EFPD					
Entire Voltage Range	316	0.59	0.200	0.176	33.9%	29.8%
	Cycle 5 (1986 - 1987)					
Entire Voltage Range	291	0.55	0.130	0.103	23.6%	18.8%

Table 3-5
Farley Unit 2 October 99
Signal Growth Statistics For Cycle 13 on an EFPY Basis

Delta Volts	Steam Generator A			Steam Generator B			Steam Generator C			Cumulative		
	Cycle 12	Cycle 13		Cycle 12	Cycle 13		Cycle 12	Cycle 13		Cycle 12	Cycle 13	
	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF
-1.2	0.0	0	0.0	0.0	1	0.005	0.0	0	0.0	0.0	1	0.002
-0.7	0.0	1	0.01	0.0	0	0.005	0.0	2	0.006	0.0	3	0.006
-0.6	0.0	0	0.01	0.0	0	0.005	0.0	1	0.009	0.0	1	0.008
-0.5	0.0	0	0.01	0.0	0	0.005	0.0	1	0.012	0.0	1	0.009
-0.4	0.0	0	0.01	0.0	1	0.009	0.0	0	0.012	0.0	1	0.011
-0.3	0.0	1	0.019	0.0	2	0.019	0.004	0	0.012	0.002	3	0.015
-0.2	0.012	1	0.029	0.013	2	0.028	0.004	3	0.021	0.008	6	0.025
-0.1	0.086	0	0.029	0.086	7	0.06	0.073	10	0.051	0.079	17	0.051
0	0.395	29	0.305	0.258	69	0.381	0.327	59	0.229	0.318	157	0.291
0.1	0.84	45	0.733	0.709	96	0.828	0.756	163	0.72	0.755	304	0.758
0.2	0.951	22	0.943	0.874	29	0.963	0.913	61	0.904	0.907	112	0.929
0.3	0.975	4	0.981	0.947	3	0.977	0.975	22	0.97	0.966	29	0.974
0.4	0.988	2	1.0	0.974	2	0.986	0.989	5	0.985	0.984	9	0.988
0.5	1.0	0		0.987	1	0.991	0.993	1	0.988	0.992	2	0.991
0.6		0		0.987	0	0.991	0.996	2	0.994	0.994	2	0.994
0.7		0		0.993	2	1.0	0.996	0	0.994	0.996	2	0.997
0.8		0		0.993	0		0.996	1	0.997	0.996	1	0.998
0.9		0		0.993	0		1.0	0	0.997	0.998	0	0.998
1		0		1.0	0			0	0.997	1.0	0	0.998
1.8		0			0			1	1.0		1	1.0
Total		105			215			332			652	

Table 3-6
Farley Unit 2 October 1999
Summary of Largest Voltage Growth Rates for BOC-13 to EOC-13

Steam Generator				Bobbin Voltage			RPC	New
SG	Row	Col	Elevation	EOC	BOC	Growth	Confirmed ?	Indication ?
C	5	81	02H	4.25	1.95	2.3	Y	N
C	22	84	01H	2.7	1.74	0.96	Y	N
B	25	79	02H	1.79	0.93	0.86	N	N
B	4	6	05H	1.58	0.76	0.82	N	Y
C	29	84	01H	4.3	3.56	0.74	Y	N
C	30	67	01H	2.68	1.98	0.7	Y	N
C	31	69	01H	2.06	1.5	0.56	Y	N
B	12	45	07H	1.25	0.71	0.54	N	N
C	5	81	01H	1.85	1.33	0.52	N	N
C	32	65	01H	2.28	1.77	0.51	Y	N
C	5	69	01H	2.17	1.68	0.49	Y	N
C	24	74	01H	2.45	1.97	0.48	Y	N
A	38	48	02H	1.25	0.79	0.46	N	N
B	34	40	01H	1.25	0.8	0.45	N	N
A	38	72	02H	1.69	1.29	0.4	N	N
B	29	16	05C	1.44	1.04	0.4	N	N
C	28	52	01H	0.7	0.3	0.4	N	Y
A	38	72	07H	1.86	1.47	0.39	N	N
C	32	79	04H	0.98	0.59	0.39	N	N
C	41	34	02H	0.87	0.48	0.39	N	Y
B	8	86	07C	1.6	1.23	0.37	N	N
B	25	87	01H	0.96	0.6	0.36	N	Y
C	33	18	01H	2.24	1.88	0.36	Y	Y
C	20	70	01H	1.57	1.21	0.36	N	N
C	3	66	01H	1.73	1.37	0.36	N	N
C	3	12	07H	1.12	0.79	0.33	N	N
C	24	78	05H	0.62	0.29	0.33	N	N
C	15	82	02H	1.27	0.95	0.32	N	N
C	37	65	01H	1.99	1.67	0.32	N	N
C	35	70	01H	2.13	1.81	0.32	Y	N

Table 3-7
Farley Unit 2 1999 EOC-13 Evaluation for Probability of Prior Cycle Detection
Composite of All Steam Generator Data

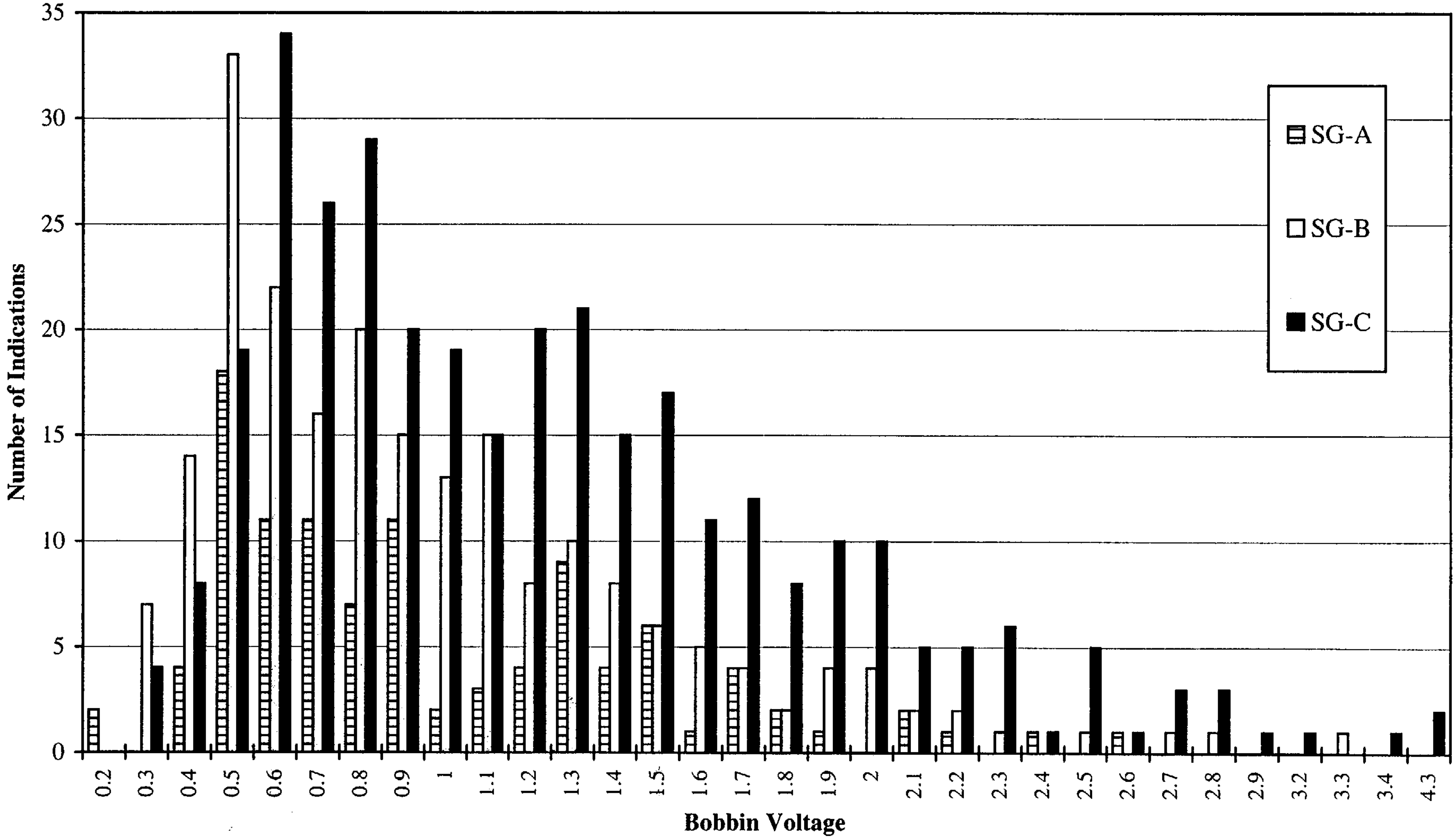
Voltage Bin	New Indications		EOC-13 Bobbin, Field Call in EOC-12 Inspection		EOC-12 Inspection Bobbin	POPCD			
	EOC-13 Inspection RPC Confirmed	EOC-13 Inspection RPC Confirmed plus not Inspected	EOC-13 Inspection RPC Confirmed	EOC-13 Inspection RPC Confirmed plus not Inspected	EOC-12 Inspection Confirmed and Plugged	RPC Confirmed Frac.	RPC Confirmed Count	RPC Confirmed Plus Not Inspected Frac.	RPC Confirmed Plus Not Inspected Count
> 0 - 0.2	0	4	0	1	0	-	0 / 0	0.200	1 / 5
0.2 - 0.4	1	33	0	31	0	0.000	0 / 1	0.484	31 / 64
0.4 - 0.6	0	25	2	114	0	1.000	2 / 2	0.820	114 / 139
0.6 -0 .8	1	27	0	89	0	0.000	0 / 1	0.767	89 / 116
0.8 - 1.0	0	16	1	59	0	1.000	1 / 1	0.787	59 / 75
1.0 - 1.5	0	32	1	114	0	1.000	1 / 1	0.781	114 / 146
1.5 - 2.0	3	13	7	54	0	0.700	7 / 10	0.806	54 / 67
2.0 - 2.5	0	0	1	1	2	1.000	3 / 3	1.000	3 / 3
> 2.5	0	0	0	0	0	-	0 / 0	-	0 / 0
TOTAL	5	150	12	463	2				
> 1V	0	0	1	1	2				

Table 3-8
Farley Unit 2
Analysis of RPC Data from EOC-12 and EOC-13 Inspections
Combined Data from All Steam Generators

Group of Indications	Total EOC-12 Inspection Bobbin Indication	Total EOC-13 Inspection Bobbin Indication	Total EOC-13 Inspection RPC Inspected	Total EOC-13 Inspection RPC Confirmed	Percent EOC-13 Inspection RPC Confirmed
Less than or Equal to 1.0 Volt in EOC-13 Inspection					
EOC-12 Inspection Bobbin Left in Service	266	264	3	2	66.7
- EOC-12 Inspection RPC Confirmed	1	1	0	0	-
- EOC-12 Inspection RPC NDD	0	0	0	0	-
- EOC-12 Inspection RPC Not Inspected	263	263	3	2	66.7
- EOC-12 Indication not found in EOC-13 Inspection*	2	-	-	-	-
New EOC-13 Inspection Indication	-	101	3	2	66.7
Sum of All EOC-13 Inspection Indication	266	365	6	4	66.7
Greater than 1.0 Volt in EOC-13 Inspection					
EOC-12 Inspection Bobbin Left in Service	231	229	39	10	25.6
- EOC-12 Inspection RPC Confirmed	0	0	0	0	-
- EOC-12 Inspection RPC NDD	27	27	25	0	0.0
- EOC-12 Inspection RPC Not Inspected	202	202	14	10	71.4
- EOC-12 Indication not found in EOC-13 Inspection*	2	-	-	-	-
New EOC-13 Inspection Indication	-	58	11	3	27.3
Sum of All EOC-13 Inspection Indication	231	287	50	13	26.0
All Voltages in EOC-13 Inspection					
EOC-12 Inspection Bobbin Left in Service	497	493	42	12	28.6
- EOC-12 Inspection RPC Confirmed	1	1	0	0	-
- EOC-12 Inspection RPC NDD	27	27	25	0	0.0
- EOC-12 Inspection RPC Not Inspected	465	465	17	12	70.6
- EOC-12 Indication not found in EOC-13 Inspection*	4	-	-	-	-
New EOC-13 Inspection Indication	-	159	14	5	35.7
Sum of All EOC-13 Inspection Indication	497	652	56	17	30.4

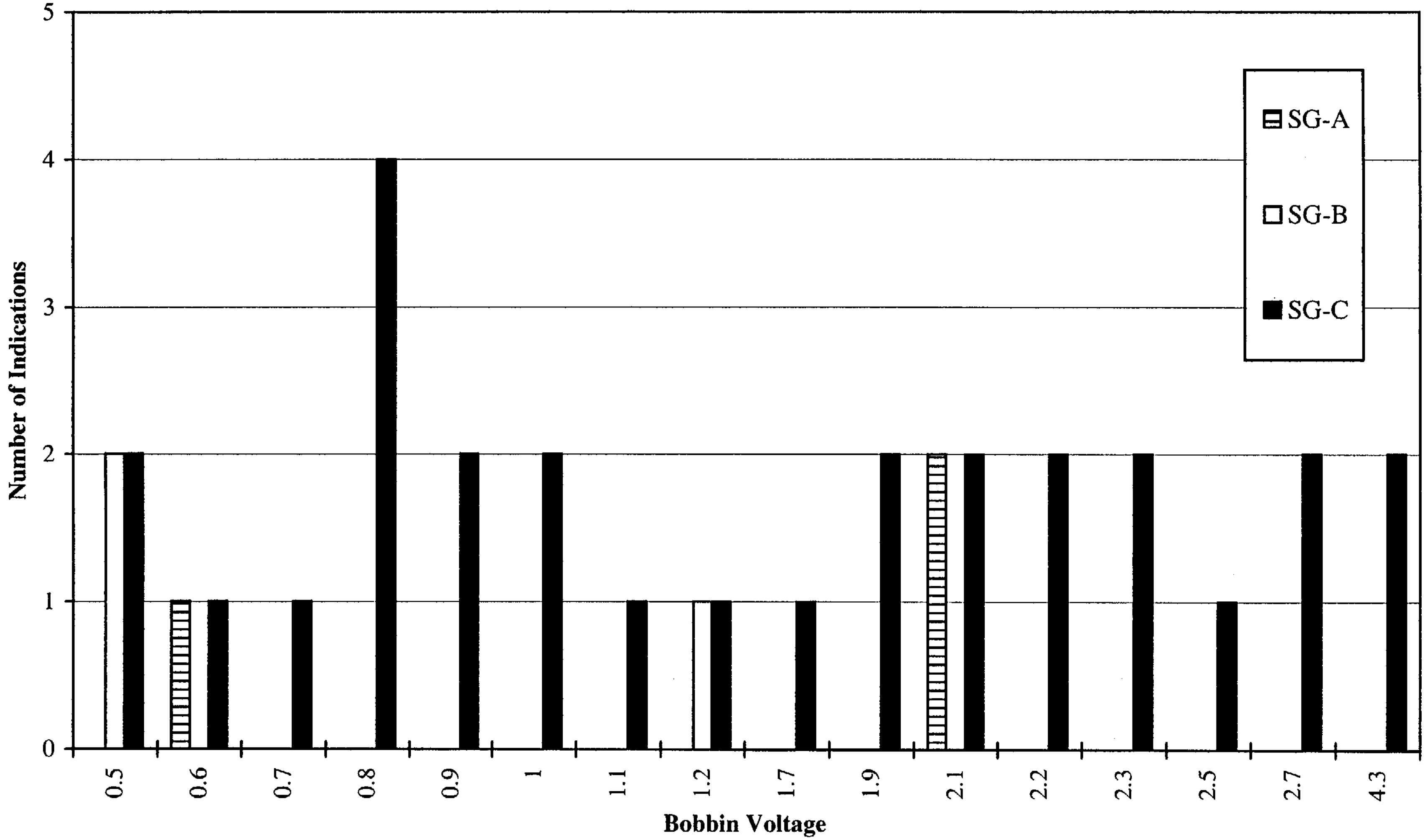
* Indications split is based on EOC-12 Inspection bobbin voltage

Figure 3-1
Farley Unit 2 October 1999 Outage
Bobbin Voltage Distributions at EOC-13 for Tubes in Service During Cycle 13



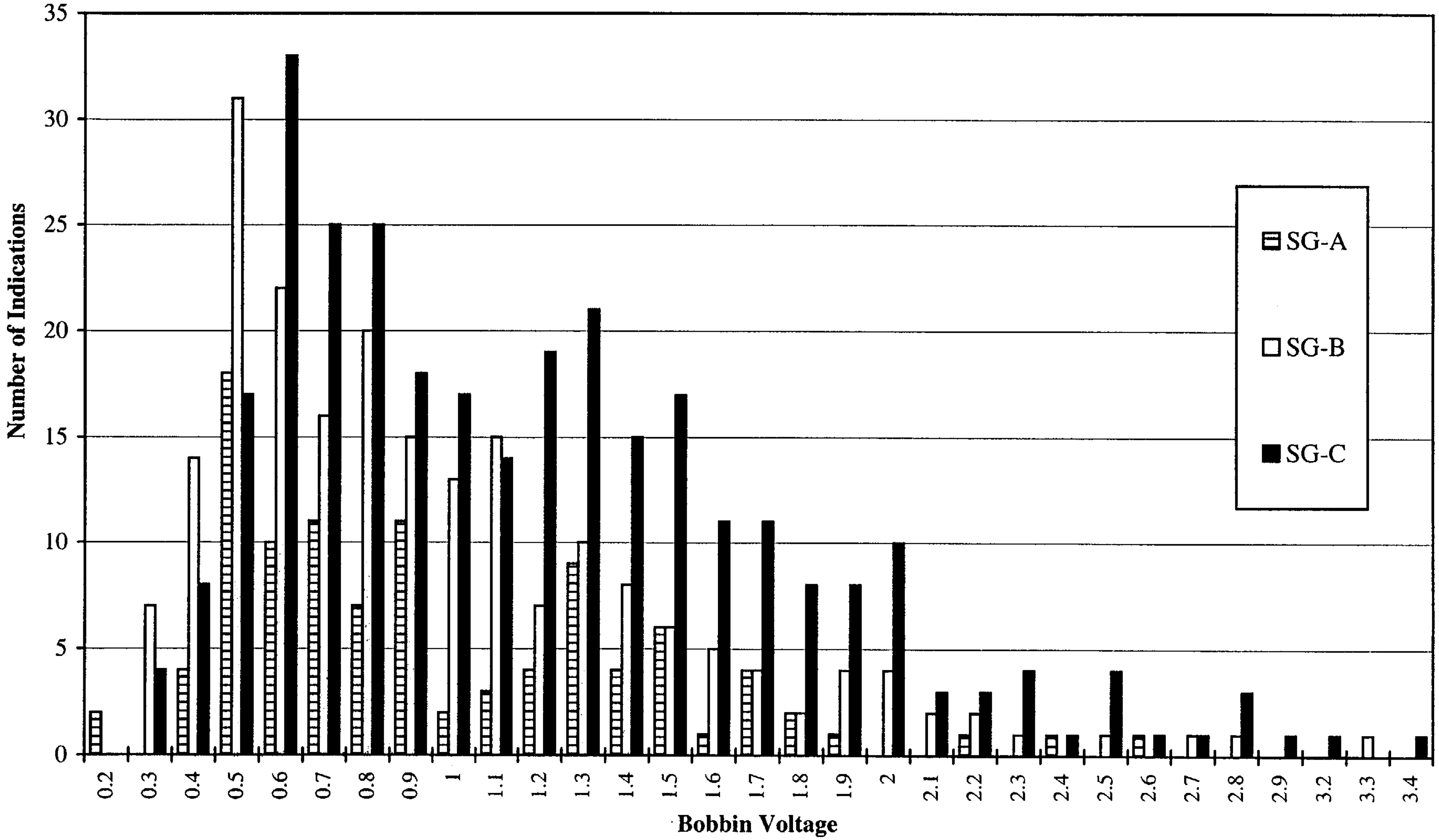
BobnrpcFig1]

Figure 3- 2
Farley Unit 2 October 1999 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 13 Service



BobnrpcFig2

Figure 3-3
Farley Unit 2 October 1999 Outage
Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 14



BobnrpcFig3

Figure 3-4
Farley Unit 2 - October 1999
ODSCC Axial Distributions for Tubes in Service During Cycle 13

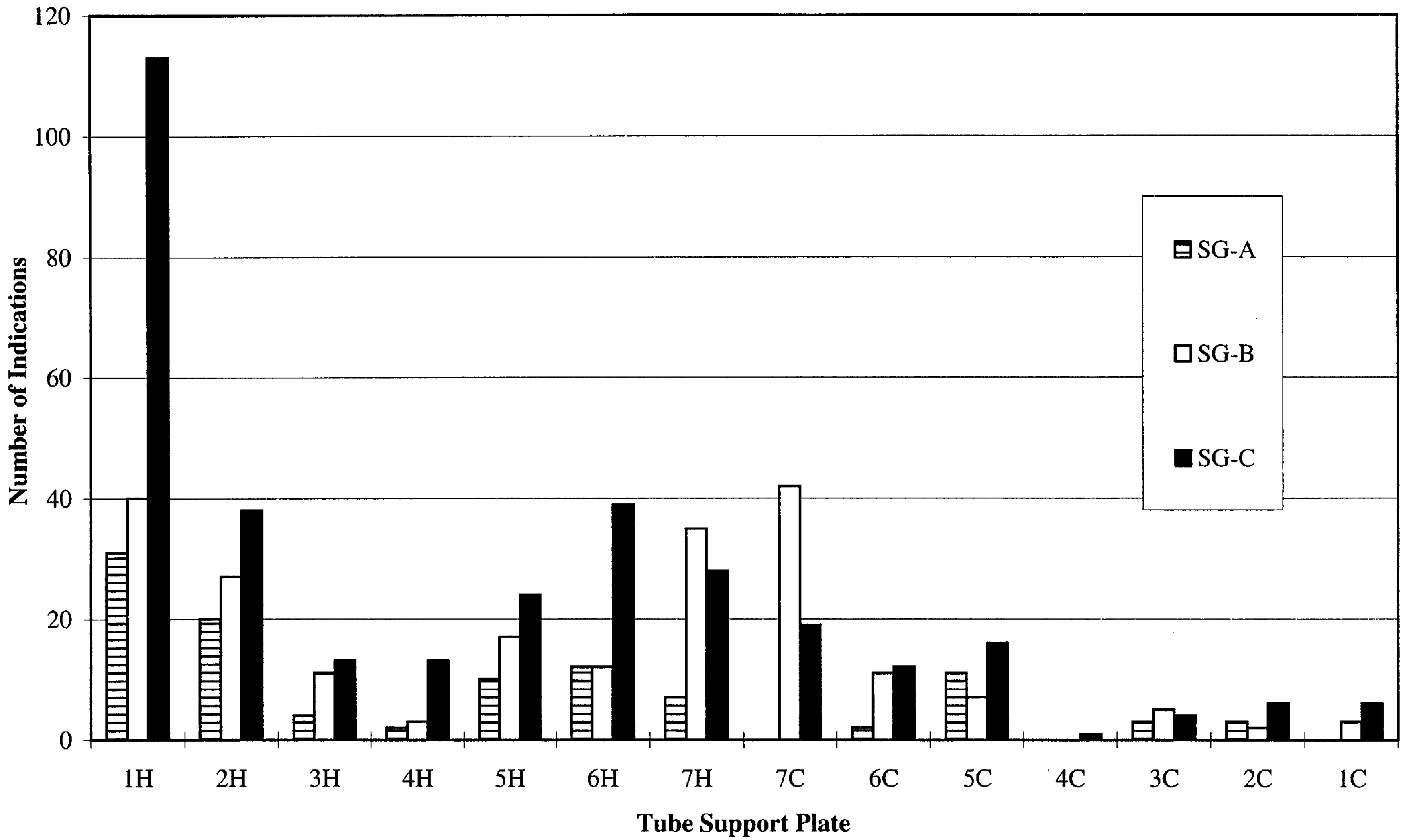


Figure 3-5
Farley Unit 2 Cycle 13 (June 1998 to September 1999)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

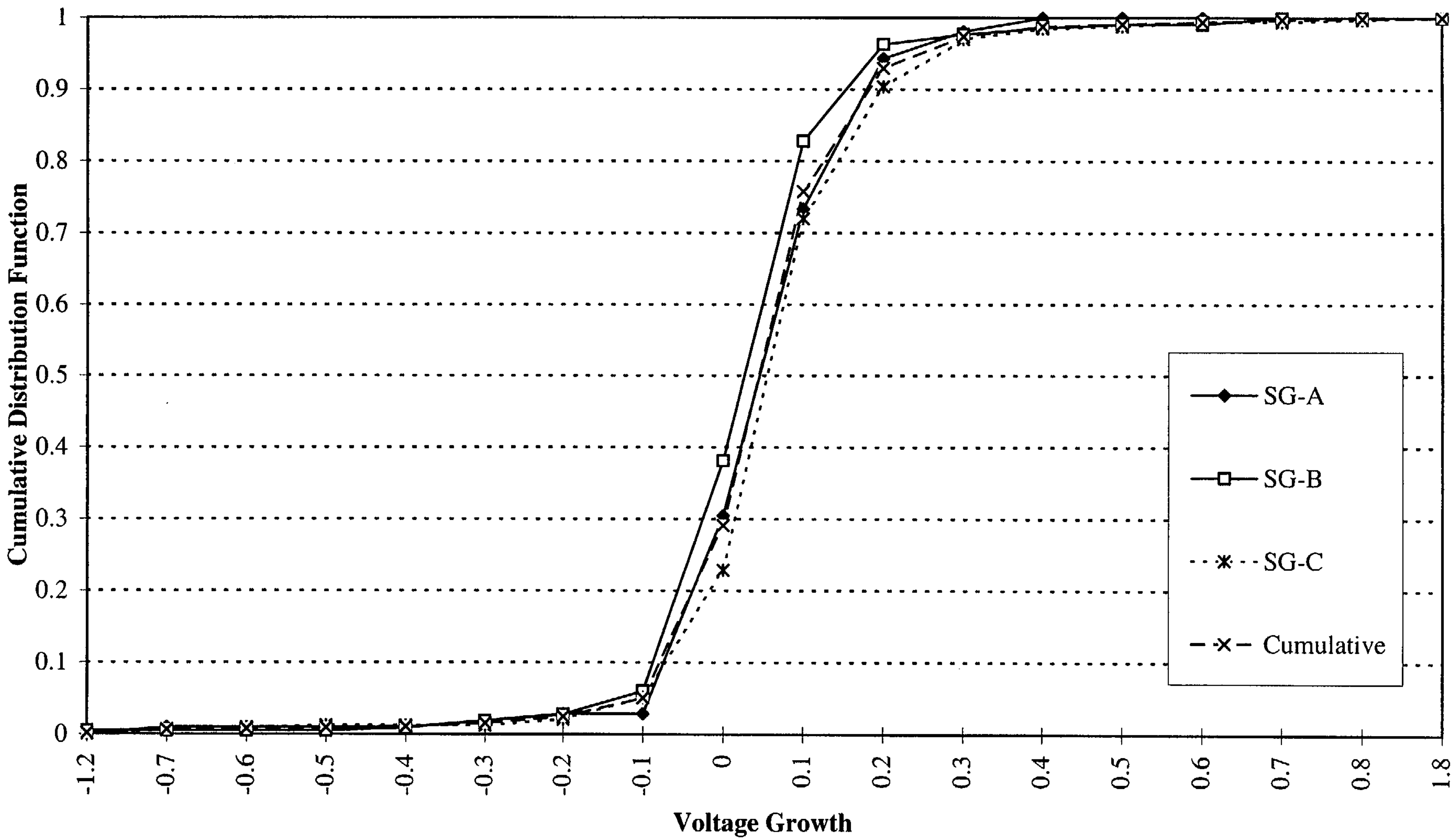


Figure 3-6
Farley Unit 2 - October 1999
Bobbin Signal Growth History - Cumulative Probability Distributions on an EFPY Basis
Composite of All Steam Generators

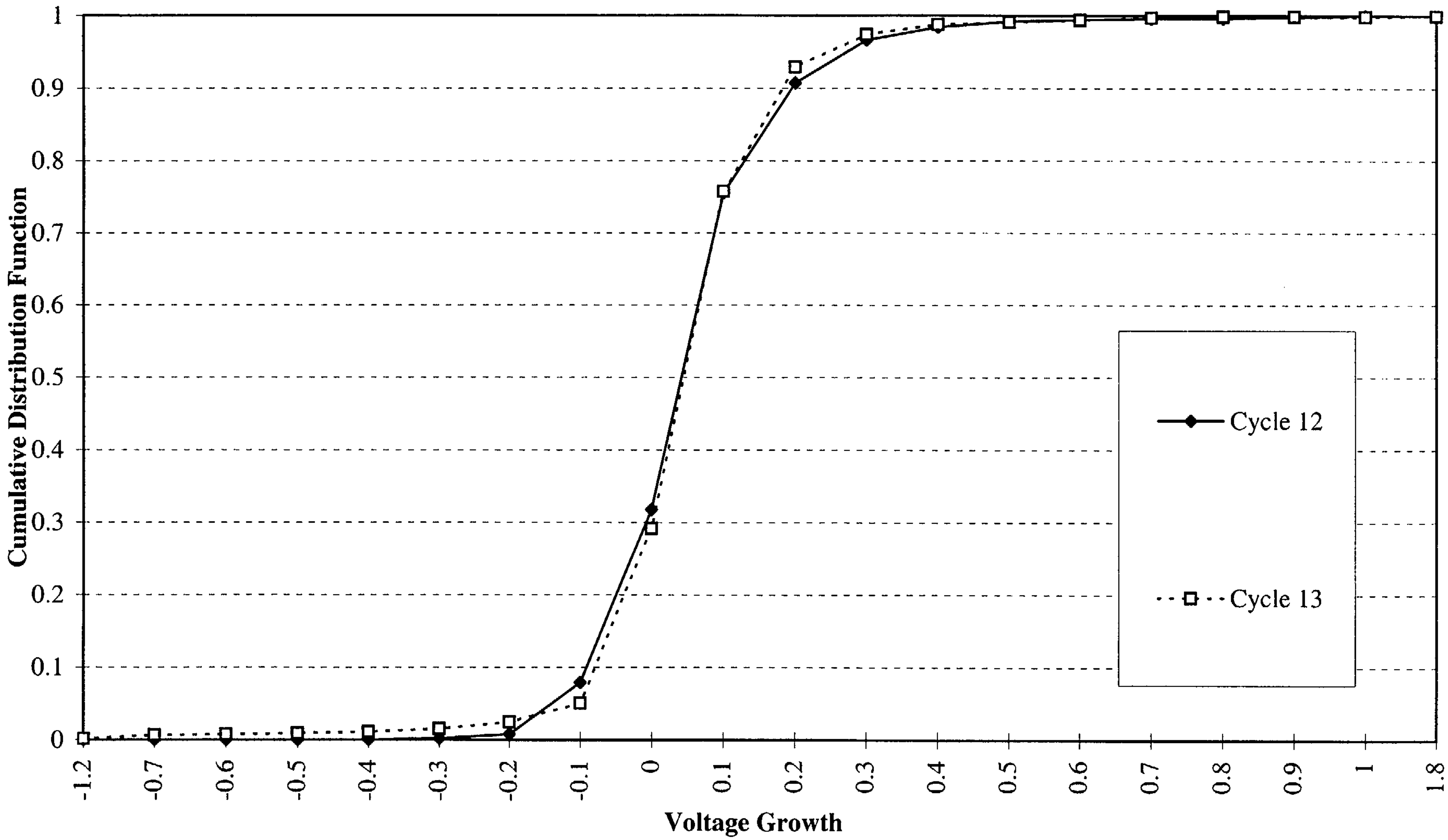
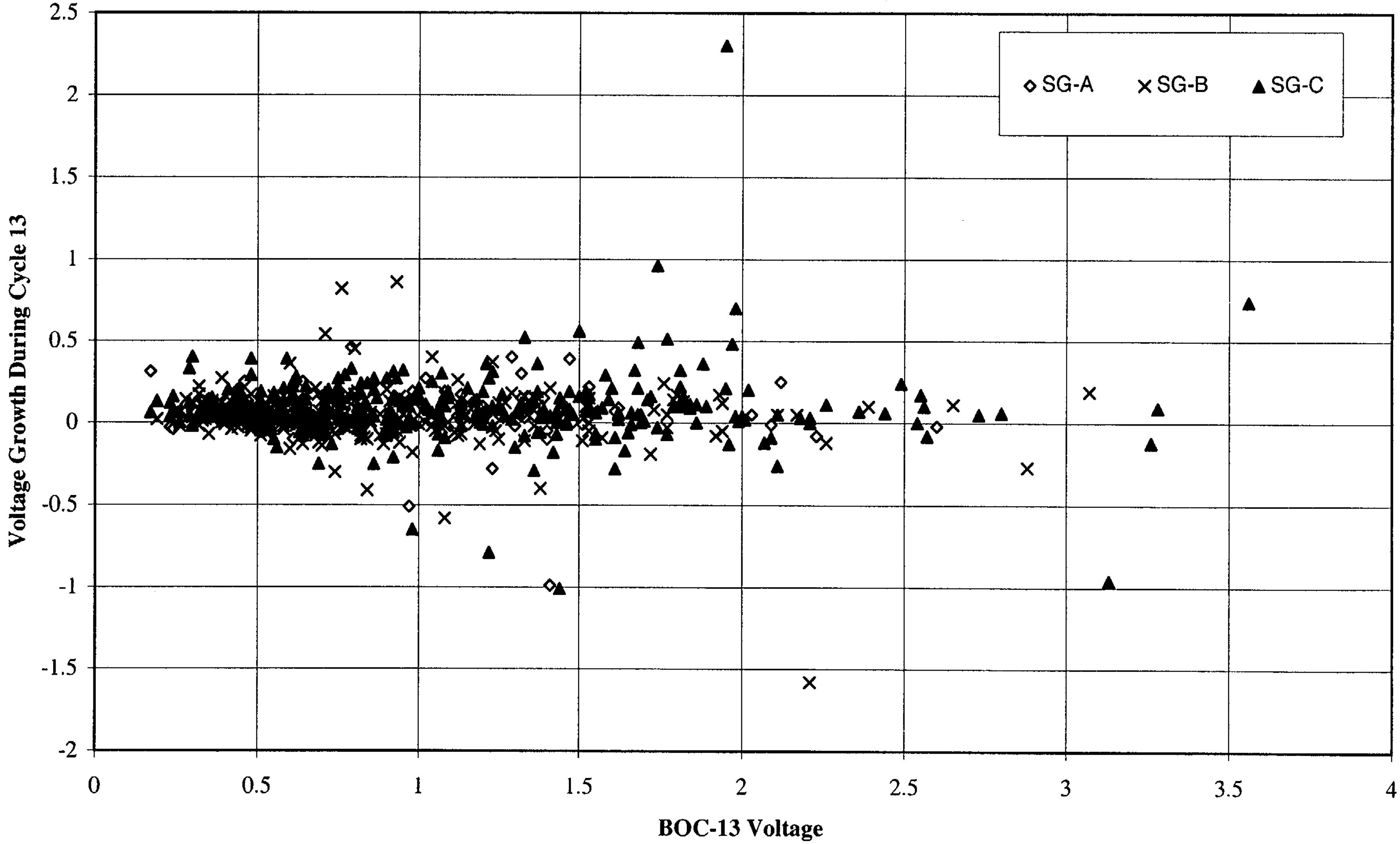
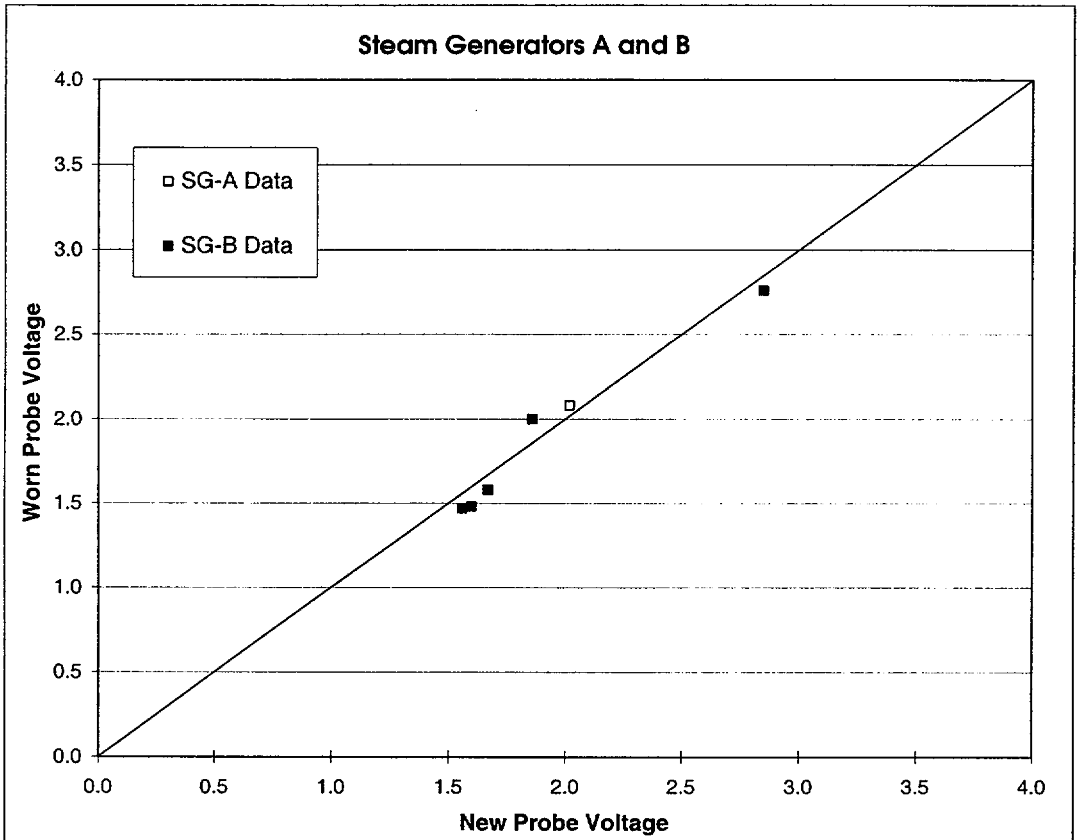


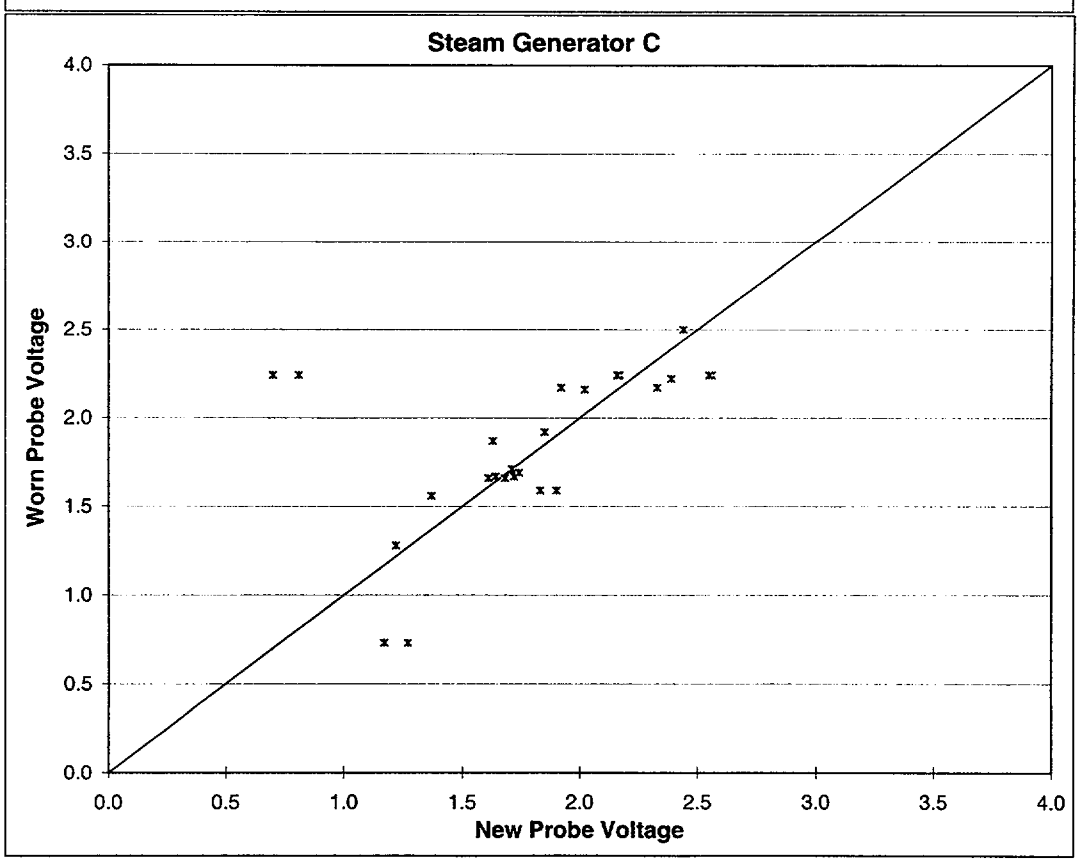
Figure 3-7
Farley Unit -2 October 1999 Outage
Voltage Growth During Cycle 13 vs BOC-13 Voltage -- All SG Data



GrowthFig3-72/6/00 11:35 AM

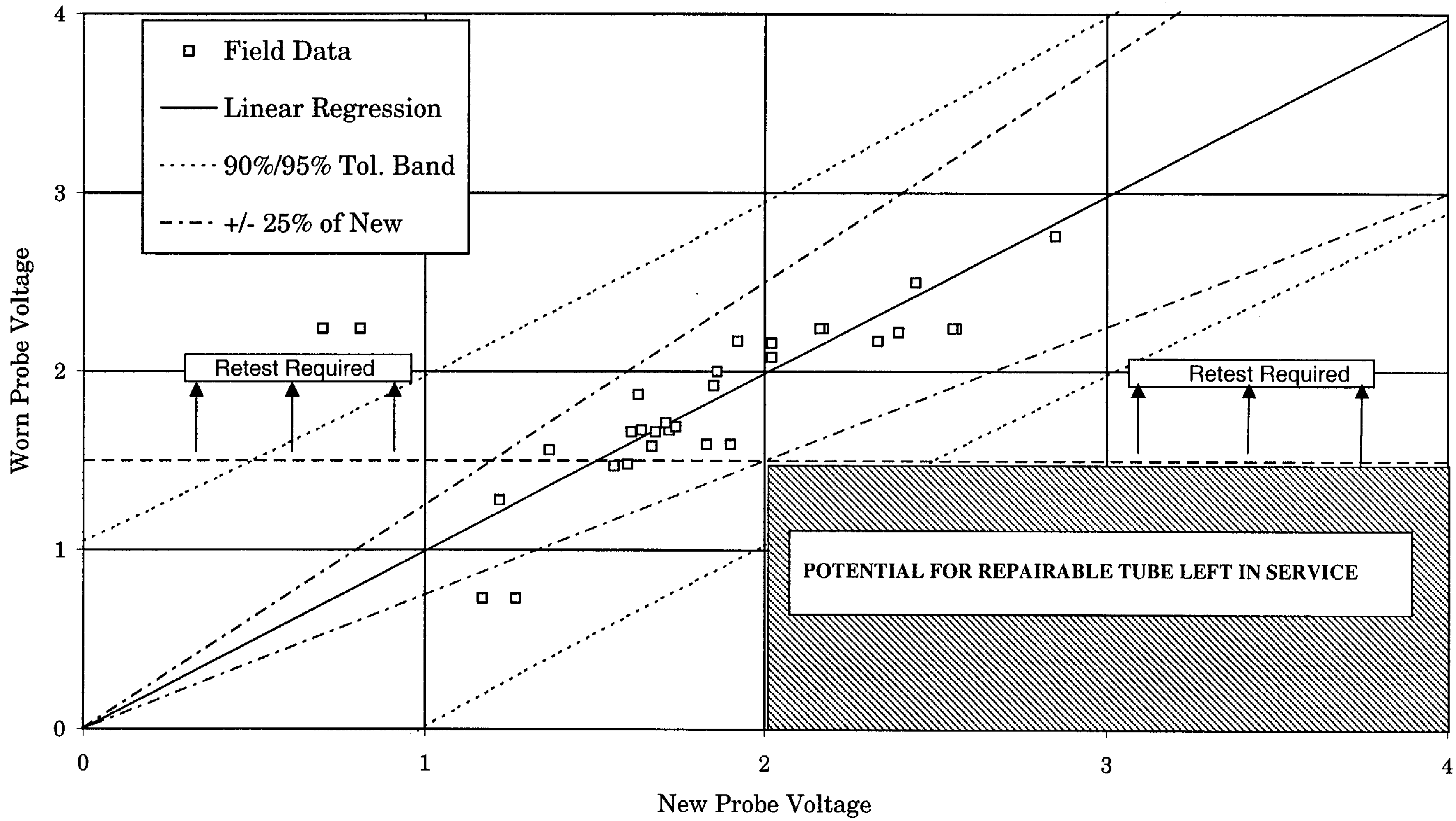
Figure 3-8
Farley Unit-1 EOC-14 Inspection
Comparison of Worn Probe Voltage Against New Probe Voltage





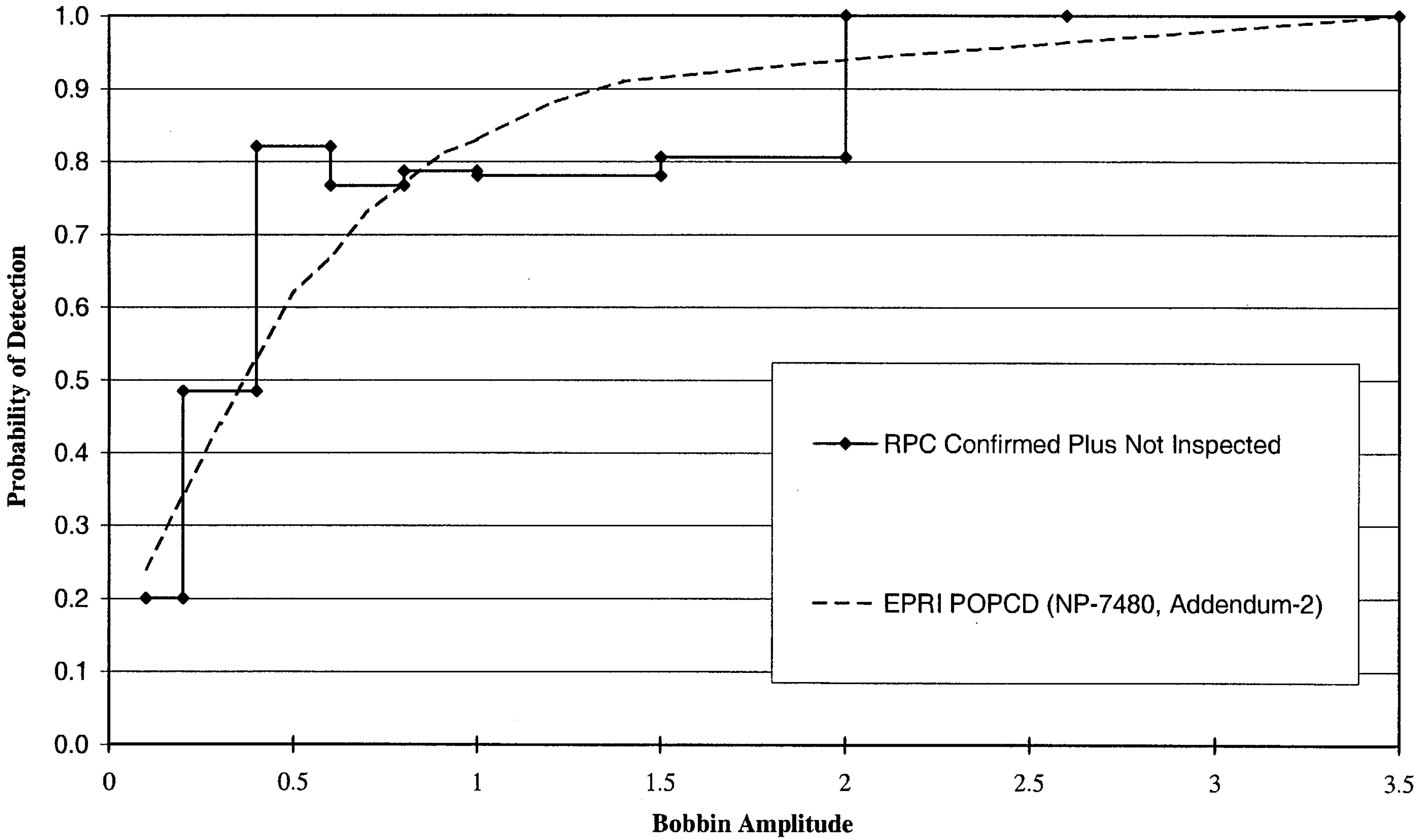
99prbwear Fig3-8 2/8/00 11:48 AM

Figure 3-9
Farley Unit-2 April 1998
Worn Probe Volts vs New Probe Volts



[99prbwear] Fig3-9 2/6/00 2:58 PM

Figure 3-10
Farley Unit 2
1999 EOC-13 Evaluation for POPCD at EOC-12



4.0 DATA BASE APPLIED FOR LEAK AND BURST CORRELATIONS

Leak and burst correlations based on the latest available database for 7/8" tubes are applied in the analyses presented in this report, and these correlations are documented in Reference 8-8. This reference database includes the latest pulled data from Farley Units 1 and 2 (from 1997 and 1996 inspections, respectively). The database meets the NRC requirement that the p value obtained from the regression analysis of leak rates be less than or equal to 5%. Therefore, a SLB leak rate versus voltage correlation is applied for the leak rate analyses of this report. The following are the correlations for burst pressure, probability of leakage and leak rate used in this report (Reference 8-8).

$$\text{Burst Pressure } (ksi) = 7.57661 - 2.39816 \times \log(volts)$$

$$\text{Probability of Leak} = \frac{1}{1 + e^{\left(4.31236 - 4.21125 \times \log(volts)\right)}}$$

$$\text{Leak Rate } (l/hr) = 10^{\left(-0.526882 + 0.987179 \times \log(volts)\right)}$$

The above leak rate equation is the same as the one in Addendum 2 of the EPRI Database Report (Reference 8-9) as there was no new leak rate data when Reference 8-8 was prepared. It corresponds to 2560 psi pressure differential across the tube wall.

The upper voltage repair limit applied at the EOC-13 inspection, documented in Reference 8-11, was developed using the database presented in Reference 8-8 which is the latest database available for 7/8" diameter tubes. The structural limit is 8.34 volts. The allowance for voltage growth is 30%/EFPY, which bounds the Farley Unit-2 data and is the minimum growth allowance required by Generic Letter 95-05. With an assumed Cycle 14 duration of 1.23 EFPY (which is slightly higher than the later defined 430 EFPD, or 1.18 EFPY, cycle length used for leak rate and burst probability projections presented in Section 7), the growth allowance becomes 36.9%. The allowance for NDE uncertainty is 20% per Generic Letter 95-05. The upper voltage repair limit is then 8.34 volts/1.569 = 5.32 volts.

5.0 SLB ANALYSIS METHODS

Monte Carlo analyses are used to calculate the SLB leak rates and tube burst probabilities for both actual EOC-13 and projected EOC-14 voltage distributions. The Monte Carlo analyses account for parameter uncertainty. The analysis methodology is described in the Westinghouse generic methods report of Reference 8-3, and it is consistent with the guidelines provided in the Generic Letter 95-05 (Reference 8-1).

In general, the methodology involves application of correlations for burst pressure, probability of leak and leak rate to a measured or calculated EOC distribution to estimate the likelihood of tube burst and primary-to-secondary leakage during a postulated SLB event. NDE uncertainties and uncertainties associated with burst pressure, leak rate probability and leak rate correlations are explicitly included by considering many thousands of voltage distributions through a Monte Carlo sampling process. The voltage distributions used in the projection analyses for the next operating cycle are obtained by applying growth data to the BOC distribution. The BOC voltage distributions include an adjustment for detection uncertainty and occurrence of new indications, in addition to the adjustments for NDE uncertainties. Comparisons of projected EOC voltage distributions with actual distributions after a cycle of operation have shown that the Monte Carlo analysis technique yields conservative estimates for EOC voltage distributions; therefore, leak and burst results based on those distributions are also conservative. Equation 3.5 in Reference 8-3 was used to determine the true BOC voltage.

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 measurement uncertainty and confidence level in voltage correlations. 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 13 = 473 EFPD (actual)   Cycle 14 = 430 EFPD (estimated)

6.3 Calculation of Voltage Distributions

Bobbin voltage projection start with a cycle initial voltage distribution that 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-2 steam generators during the last two operating periods, as represented by their CPDFs, are shown on Table 3-5. 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 growth distributions for Cycles 12 and 13 are comparable to each other; however, the top growth value for Cycle 13 is nearly twice as large as the largest Cycle 12 growth. Therefore, Cycle 13 growth distribution is more limiting, and it was applied to obtain EOC-14 projections. Further conservatism for the EOC-14 bobbin voltage prediction is provided by using the composite growth distribution for SGs A and B (since their own growth rates are smaller than the composite growth rate) and its own growth rate distribution for SG-C (since it is higher than the composite growth rate). This approach is recommended in Reference 8-3. Growth data were represented by a histogram in the Monte Carlo analyses.

For each SG, the initial bobbin voltage distribution of indications being returned to service for the next cycle (BOC-14) is derived from the actual EOC-13 inspection results adjusted for tubes that are taken out of service by plugging. The BOC-14 bobbin voltage distributions obtained are summarized on Table 6-1. The table shows EOC-13 bobbin voltage indications, the subsequent plugged indications (which were in service for Cycle 13 and then taken out of service, albeit not all for reasons of ODSCC at TSP), and the BOC-14 indications corresponding to a constant POD value of 0.6 as well as the voltage dependent generic POPCD. The POPCD distribution used is shown in Figure 6-1.

6.4 Predicted EOC-14 Voltage Distributions

The licensing-basis calculations to predict EOC-14 bobbin voltage distributions were performed for all SGs with a constant POD value of 0.6 in accordance with a NRC requirement. In addition, calculations were also performed using a voltage dependent generic POPCD distribution developed based on bobbin and RPC data from 18 EC inspections at 10 different plants. The development of a generic POPCD distribution is described in Reference 8-9.

Table 6-2 provides the EOC-14 voltage distributions predicted using the BOC-14 voltage distribution shown in Table 6-1. As anticipated, the largest number of indications is predicted for SG-C, 525 indications for a constant POD of 0.6. The assumed BOC-14 and predicted EOC-14 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-14 is in SG-C, and its magnitude is 5.1 volts for a constant POD of 0.6

6.5 Comparison of Predicted and Actual EOC-13 Voltage Distributions

The actual EOC-13 bobbin voltage distributions and the corresponding predictions presented in the last 90-day report (Reference 8-4), are compared in Table 6-3 and on Figure 6-5. SG-C was predicted to be limiting at EOC-13 which is consistent with the actual measurements since this SG has the highest number of indications as well as the largest indication found in the EOC-13 inspection. The total number of indications for all SGs is overpredicted by 16% to 37% in the licensing-basis analysis with POD of 0.6. Also, the licensing-basis analysis overpredicted by 60% to 100% the actual EOC-13 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. EOC-13 voltage projections based on the voltage-dependent POPCD also yield conservative results. While the total indication population for SG-B is under predicted by a small amount (about 10%), the indication population over 1 volt as well as the population above 2 volts are 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 2 October 1999
EOC-13 Bobbin and Assumed BOC-14 Bobbin Distributions in SLB Leak Rate and Tube Burst Analyses

Voltage Bin	Steam Generator A				Steam Generator B				Steam Generator C			
	EOC - 13		BOC - 14		EOC - 13		BOC - 14		EOC - 13		BOC - 14	
	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
0.2	2	0	3.33	5.56	0	0	0.00	0.00	0	0	0.00	0.00
0.3	0	0	0.00	0.00	7	0	11.67	15.22	4	0	6.67	8.70
0.4	4	0	6.67	7.41	14	0	23.33	25.93	8	0	13.33	14.81
0.5	18	0	30.00	28.57	33	2	53.00	50.38	19	2	29.67	28.16
0.6	11	1	17.33	14.94	22	0	36.67	31.88	34	1	55.67	48.28
0.7	11	0	18.33	14.67	16	0	26.67	21.33	26	1	42.33	33.67
0.8	7	0	11.67	8.86	20	0	33.33	25.32	29	4	44.33	32.71
0.9	11	0	18.33	13.41	15	0	25.00	18.29	20	2	31.33	22.39
1	2	0	3.33	2.38	13	0	21.67	15.48	19	2	29.67	20.62
1.1	3	0	5.00	3.51	15	0	25.00	17.54	15	1	24.00	16.54
1.2	4	0	6.67	4.60	8	1	12.33	8.20	20	1	32.33	21.99
1.3	9	0	15.00	10.23	10	0	16.67	11.36	21	0	35.00	23.86
1.4	4	0	6.67	4.49	8	0	13.33	8.99	15	0	25.00	16.85
1.5	6	0	10.00	6.67	6	0	10.00	6.67	17	0	28.33	18.89
1.6	1	0	1.67	1.10	5	0	8.33	5.49	11	0	18.33	12.09
1.7	4	0	6.67	4.37	4	0	6.67	4.37	12	1	19.00	12.11
1.8	2	0	3.33	2.17	2	0	3.33	2.17	8	0	13.33	8.70
1.9	1	0	1.67	1.08	4	0	6.67	4.32	10	2	14.67	8.81
2	0	0	0.00	0.00	4	0	6.67	4.30	10	0	16.67	10.75
2.1	2	2	1.33	0.14	2	0	3.33	2.14	5	2	6.33	3.35
2.2	1	0	1.67	1.06	2	0	3.33	2.13	5	2	6.33	3.32
2.3	0	0	0.00	0.00	1	0	1.67	1.06	6	2	8.00	4.35
2.4	1	0	1.67	1.05	0	0	0.00	0.00	1	0	1.67	1.05
2.5	0	0	0.00	0.00	1	0	1.67	1.05	5	1	7.33	4.24
2.6	1	0	1.67	1.04	0	0	0.00	0.00	1	0	1.67	1.04
2.7	0	0	0.00	0.00	1	0	1.67	1.04	3	2	3.00	1.11
2.8	0	0	0.00	0.00	1	0	1.67	1.03	3	0	5.00	3.09
2.9	0	0	0.00	0.00	0	0	0.00	0.00	1	0	1.67	1.03
3.2	0	0	0.00	0.00	0	0	0.00	0.00	1	0	1.67	1.01
3.3	0	0	0.00	0.00	1	0	1.67	1.01	0	0	0.00	0.00
3.4	0	0	0.00	0.00	0	0	0.00	0.00	1	0	1.67	1.00
4.3	0	0	0.00	0.00	0	0	0.00	0.00	2	2	1.33	0.00
Total	105	3	172.00	137.32	215	3	355.33	286.70	332	28	525.33	384.52
> 1V	39	2	63.00	41.52	75	1	124.00	82.87	173	16	272.33	175.19
> 2V	5	2	6.33	3.30	9	0	15.00	9.45	34	11	45.67	24.59

Table 6-2
Farley Unit 2 October 1999
Voltage Distribution Projection for EOC - 14

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C	
	Projected Number of Indications at EOC - 14					
	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD
0.1	0.05	0.08	0.00	0.00	0.00	0.00
0.2	0.83	1.39	0.33	0.43	0.15	0.19
0.3	1.61	2.53	3.72	4.66	1.69	2.12
0.4	3.86	4.40	12.66	14.46	6.41	7.40
0.5	10.49	10.45	25.12	25.92	14.95	15.27
0.6	16.96	15.90	34.40	32.91	27.29	25.36
0.7	18.15	16.07	35.05	31.36	37.88	32.87
0.8	16.80	13.97	32.08	26.84	41.10	33.64
0.9	14.75	11.66	29.26	23.07	39.36	30.54
1.0	12.15	9.24	26.60	20.06	35.50	26.40
1.1	9.39	6.96	24.09	17.58	32.10	23.07
1.2	7.84	5.64	21.53	15.33	30.44	21.31
1.3	7.66	5.38	18.51	12.96	29.76	20.54
1.4	7.95	5.49	15.30	10.58	28.86	19.72
1.5	7.90	5.39	12.48	8.54	27.18	18.37
1.6	7.25	4.91	10.35	7.00	24.67	16.52
1.7	6.21	4.16	8.73	5.85	21.85	14.48
1.8	5.01	3.32	7.48	4.98	19.09	12.45
1.9	3.88	2.53	6.45	4.26	16.61	10.70
2.0	2.92	1.85	5.56	3.65	14.42	9.13
2.1	2.19	1.34	4.75	3.10	12.45	7.74
2.2	1.67	0.99	3.97	2.57	10.62	6.50
2.3	1.32	0.76	3.24	2.09	8.95	5.38
2.4	1.07	0.61	2.61	1.70	7.50	4.45
2.5	0.89	0.51	2.10	1.36	6.27	3.68
2.6	0.77	0.45	1.70	1.10	5.29	3.09
2.7	0.62	0.37	1.37	0.88	4.46	2.60
2.8	0.49	0.11	1.10	0.71	3.74	2.17
2.9	0.32	0.00	0.90	0.57	3.10	1.79
3.0	0.00	0.70	0.74	0.47	2.54	1.46
3.1	0.70	0.00	0.62	0.39	2.06	1.19
3.2	0.00	0.30	0.51	0.32	1.67	0.97
3.3	0.00	0.00	0.43	0.26	1.35	0.78
3.4	0.30	0.00	0.35	0.00	1.08	0.63
3.5	0.00	0.00	0.26	0.00	0.86	0.50
3.6	0.00	0.00	0.00	0.70	0.69	0.39
3.7	0.00	0.00	0.00	0.00	0.55	0.26
3.8	0.00	0.00	0.70	0.00	0.44	0.00
3.9	0.00	0.00	0.00	0.30	0.36	0.00
4.0	0.00	0.00	0.00	0.00	0.30	0.70
4.1	0.00	0.00	0.30	0.00	0.26	0.00
4.2	0.00	0.00	0.00	0.00	0.22	0.30
4.3	0.00	0.00	0.00	0.00	0.19	0.00
4.4	0.00	0.00	0.00	0.00	0.07	0.00
4.7	0.00	0.00	0.00	0.00	0.70	0.00
5.1	0.00	0.00	0.00	0.00	0.30	0.00
TOTAL	172.00	137.46	355.35	286.96	525.33	384.66
> 1 V	76.35	51.77	156.13	107.25	321.00	210.87
> 2 V	10.34	6.14	25.65	16.52	76.02	44.58

Table 6-3
Farley Unit 2 October 1999
Comparison of Predicted and Actual EOC-13 Voltage Distributions

Voltage Bin	Steam Generator A			Steam Generator B			Steam Generator C		
	Number of Indications								
	EOC-13 Prediction		EOC-13 Actual	EOC-13 Prediction		EOC-13 Actual	EOC-13 Prediction		EOC-13 Actual
	POD = 0.6	POPCD		POD = 0.6	POPCD		POD = 0.6	POPCD	
0.2	0.07	0.09	2	0.28	0.37	0	0.49	0.64	0
0.3	0.99	1.20	0	3.18	3.97	7	4.54	5.79	4
0.4	4.48	4.77	4	8.68	9.69	14	8.58	9.66	8
0.5	10.19	9.98	18	14.85	14.99	33	17.84	17.46	19
0.6	13.21	12.19	11	18.73	17.42	22	27.43	24.83	34
0.7	13.03	11.36	11	20.61	17.80	16	32.17	27.51	26
0.8	11.41	9.45	7	21.47	17.42	20	32.68	26.53	29
0.9	9.57	7.59	11	20.57	16.03	15	31.62	24.72	20
1.0	7.88	6.03	2	18.48	13.93	13	29.53	22.36	19
1.1	6.85	5.09	3	16.63	12.19	15	27.13	20.08	15
1.2	6.60	4.72	4	15.22	10.88	8	24.82	18.06	20
1.3	6.89	4.82	9	13.63	9.57	10	22.86	16.38	21
1.4	7.11	4.91	4	11.73	8.14	8	21.40	15.05	15
1.5	6.78	4.64	6	9.84	6.77	6	20.23	14.02	17
1.6	5.83	3.96	1	8.28	5.63	5	18.92	12.91	11
1.7	4.60	3.11	4	7.14	4.79	4	17.36	11.74	12
1.8	3.42	2.30	2	6.22	4.14	2	15.70	10.55	8
1.9	2.53	1.69	1	5.36	3.55	4	13.89	9.27	10
2.0	1.95	1.29	0	4.52	2.99	4	12.20	8.11	10
2.1	1.58	1.02	2	3.72	2.45	2	10.68	7.09	5
2.2	1.34	0.85	1	3.01	2.00	2	9.30	6.16	5
2.3	1.17	0.72	0	2.40	1.60	1	8.12	5.34	6
2.4	0.97	0.59	1	1.92	1.28	0	7.15	4.70	1
2.5	0.77	0.44	0	1.57	1.03	1	6.22	4.05	5
2.6	0.59	0.33	1	1.34	0.88	0	5.33	3.44	1
2.7	0.44	0.24	0	1.20	0.78	1	4.51	2.89	3
2.8	0.34	0.01	0	1.09	0.70	1	3.81	2.44	3
2.9	0.26	0.00	0	1.01	0.64	0	3.19	2.03	1
3.0	0.16	0.00	0	0.93	0.58	0	2.66	1.69	0
3.1	0.00	0.70	0	0.84	0.53	0	2.22	1.41	0
3.2	0.00	0.00	0	0.73	0.46	0	1.85	1.17	1
3.3	0.70	0.00	0	0.62	0.38	1	1.55	0.97	0
3.4	0.00	0.00	0	0.51	0.32	0	1.28	0.81	1
3.5	0.00	0.00	0	0.41	0.26	0	1.06	0.66	0
3.6	0.00	0.00	0	0.33	0.20	0	0.86	0.54	0
3.7	0.00	0.30	0	0.25	0.10	0	0.69	0.43	0
3.8	0.00	0.00	0	0.19	0.00	0	0.55	0.34	0
3.9	0.00	0.00	0	0.14	0.00	0	0.44	0.27	0
4.0	0.00	0.00	0	0.02	0.00	0	0.39	0.26	0
4.1	0.00	0.00	0	0.00	0.70	0	0.33	0.23	0
4.2	0.00	0.00	0	0.00	0.00	0	0.34	0.25	0
4.3	0.30	0.00	0	0.70	0.00	0	0.35	0.26	2
4.4	0.00	0.00	0	0.00	0.00	0	0.31	0.23	0
4.5	0.00	0.00	0	0.00	0.00	0	0.26	0.19	0
4.6	0.00	0.00	0	0.00	0.30	0	0.22	0.02	0
4.7	0.00	0.00	0	0.00	0.00	0	0.19	0.00	0
4.8	0.00	0.00	0	0.30	0.00	0	0.13	0.00	0
4.9	0.00	0.00	0	0.00	0.00	0	0.00	0.70	0
5.2	0.00	0.00	0	0.00	0.00	0	0.70	0.00	0
5.4	0.00	0.00	0	0.00	0.00	0	0.00	0.30	0
5.7	0.00	0.00	0	0.00	0.00	0	0.30	0.00	0
TOTAL	132.01	104.39	105.00	248.65	195.46	215.00	454.38	344.54	332.00
> 1 V	61.18	41.73	39.00	121.80	83.84	75.00	269.50	185.04	173.00
> 2 V	8.62	5.20	5.00	23.23	15.19	9.00	74.99	48.87	34.00

Figure 6-1
Generic POPCD Distribution Based on 15 Inspections in 8 Plants
[Presented in EPRI Report NP-7480, Addendum-2]

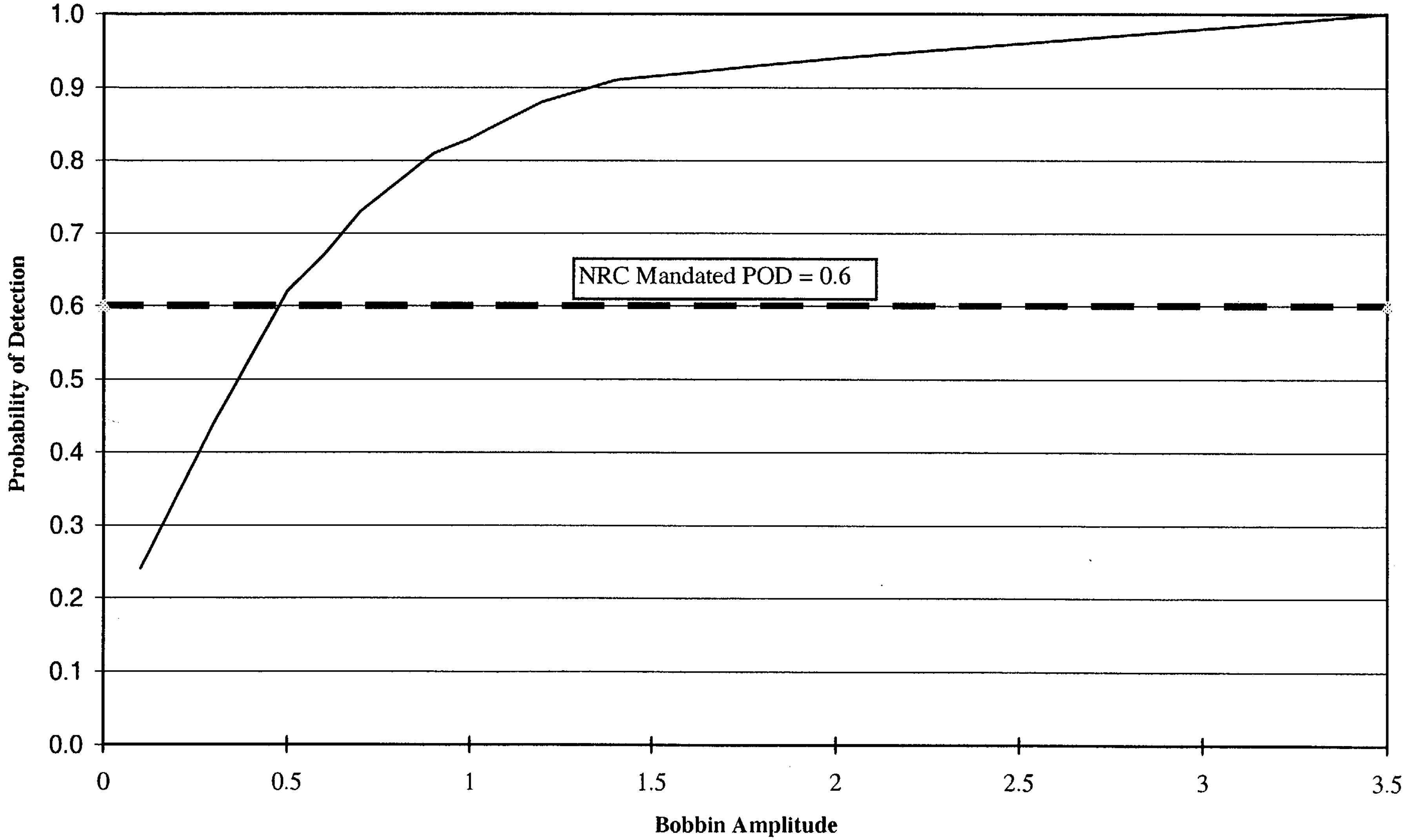


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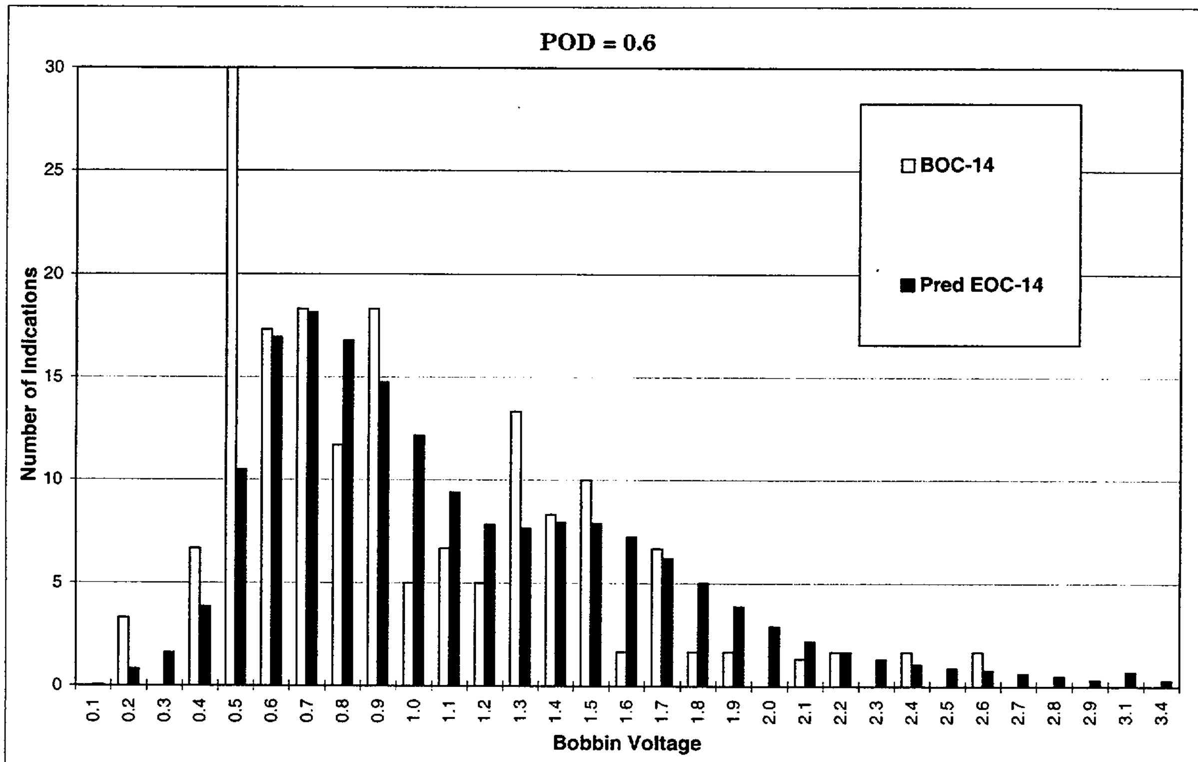
Figure 6-2
Farley Unit 2 SG-A
Predicted Bobbin Voltage Distribution for Cycle 14



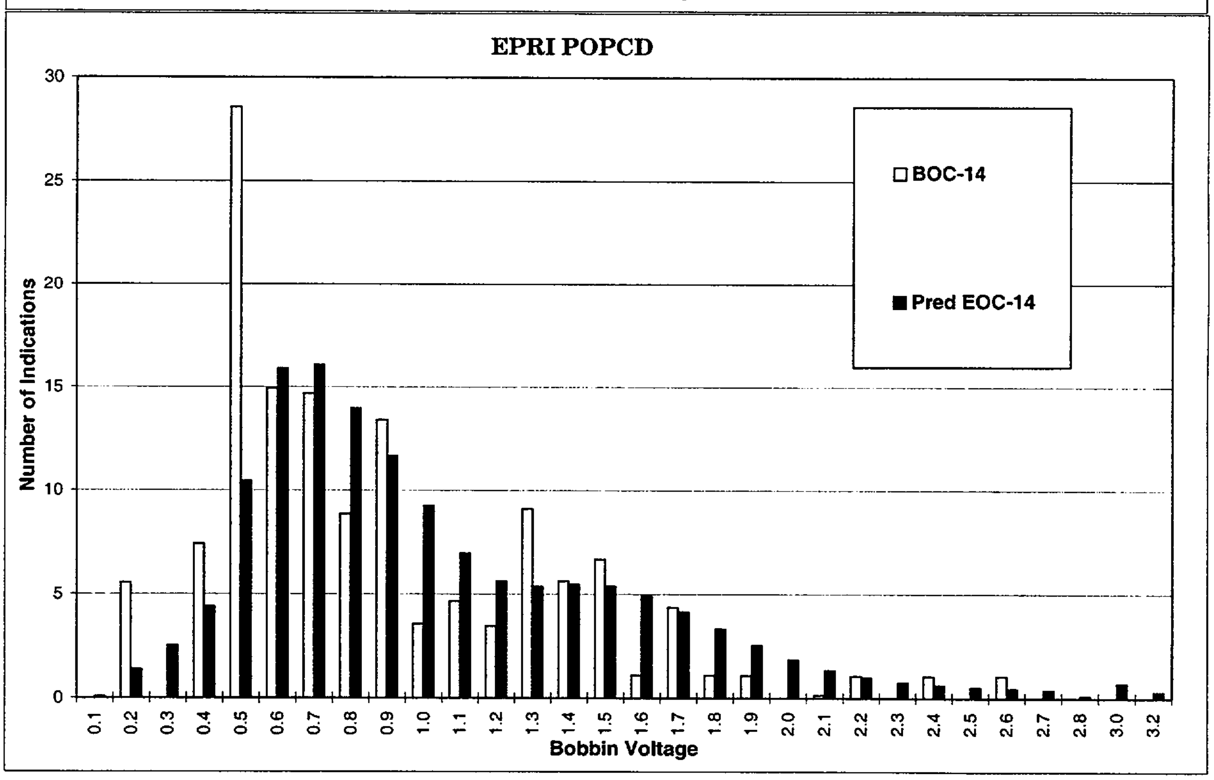
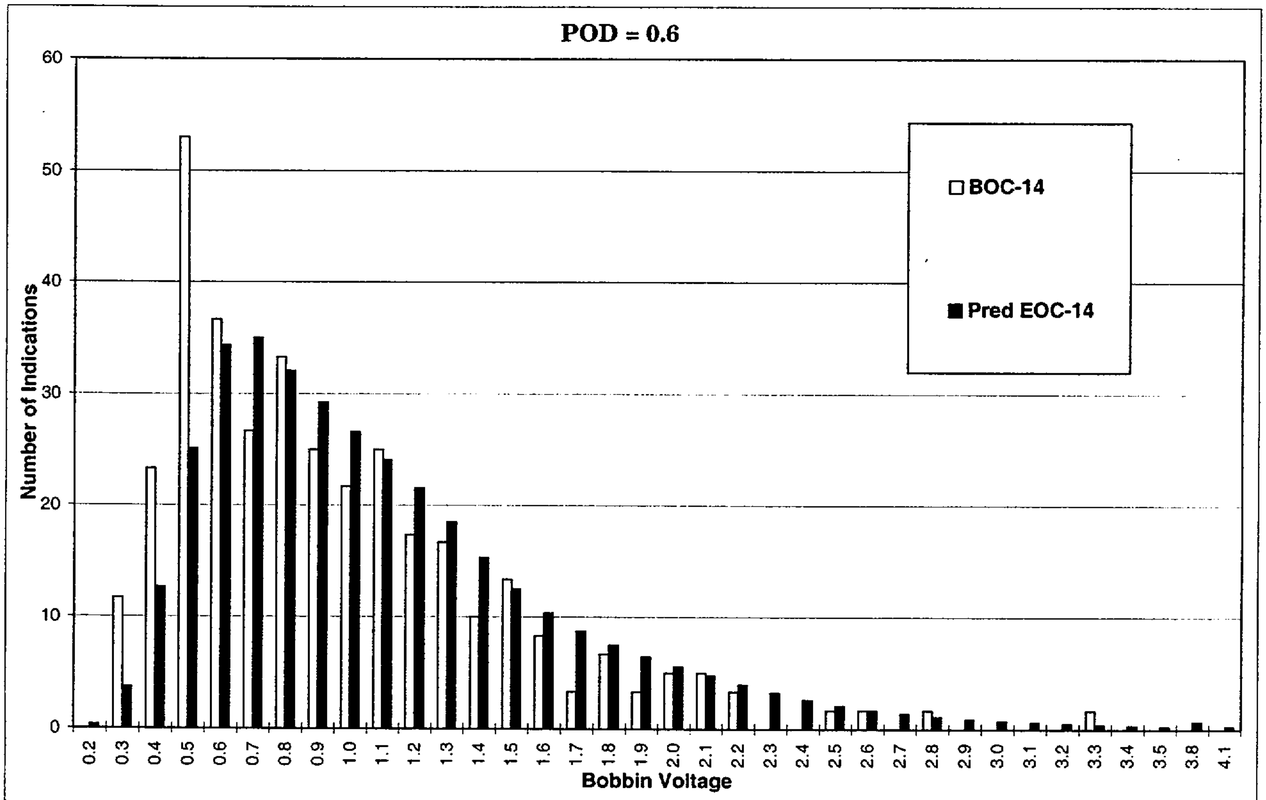


Figure 6-3
Farley Unit 2 SG-B
Predicted Bobbin Voltage Distribution for Cycle 14



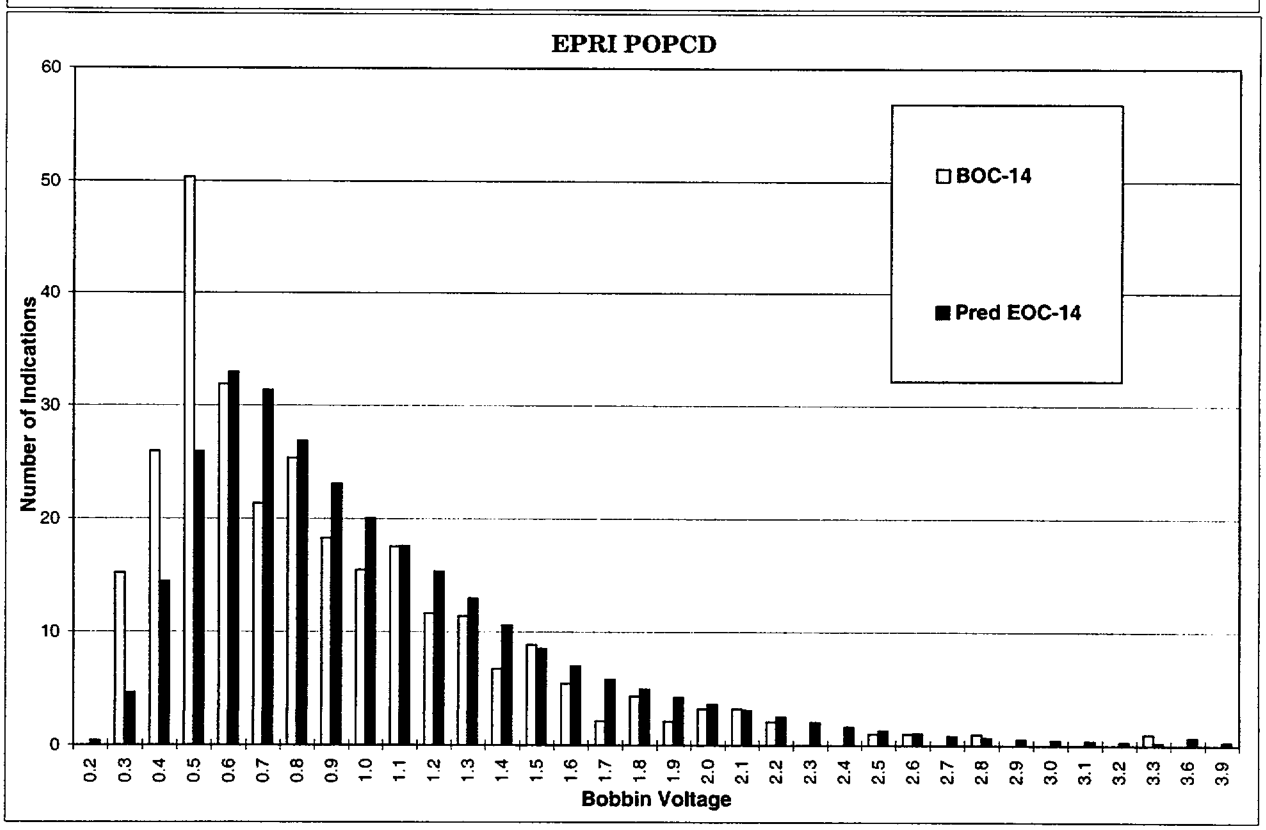
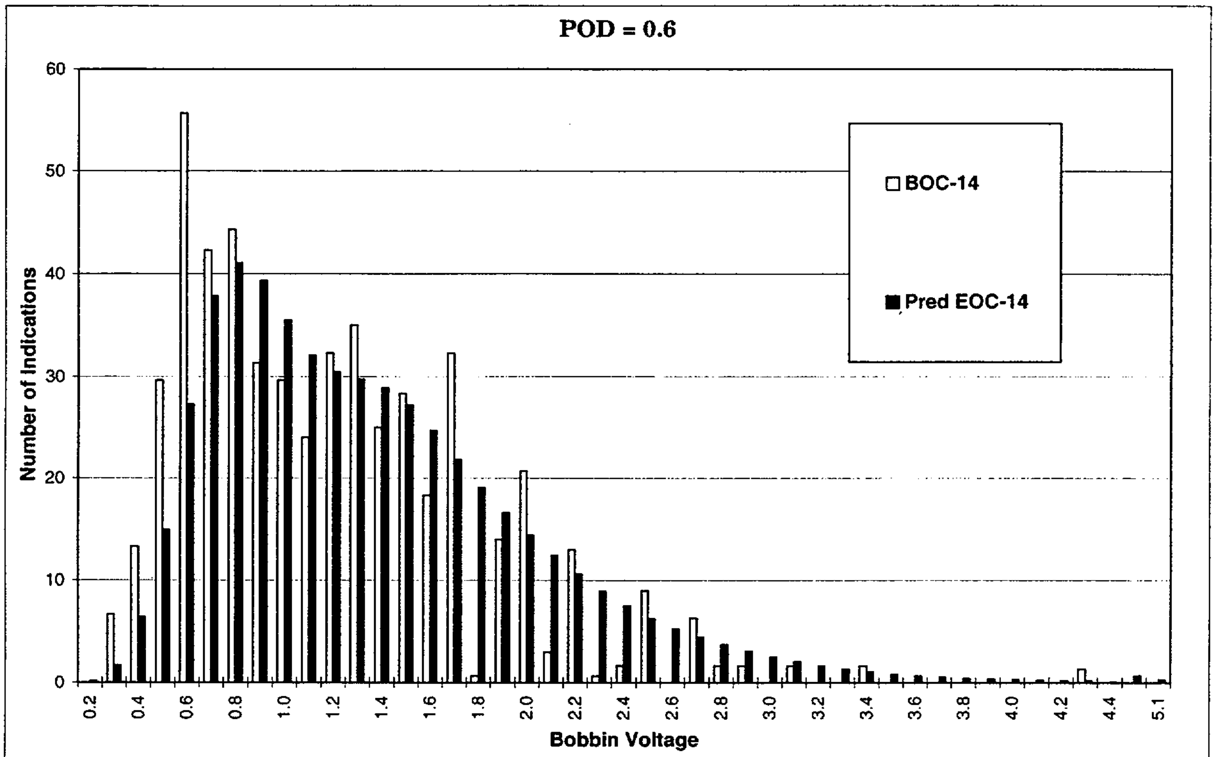


Figure 6-4
Farley Unit 2 SG-C
Predicted Bobbin Voltage Distribution for Cycle 14



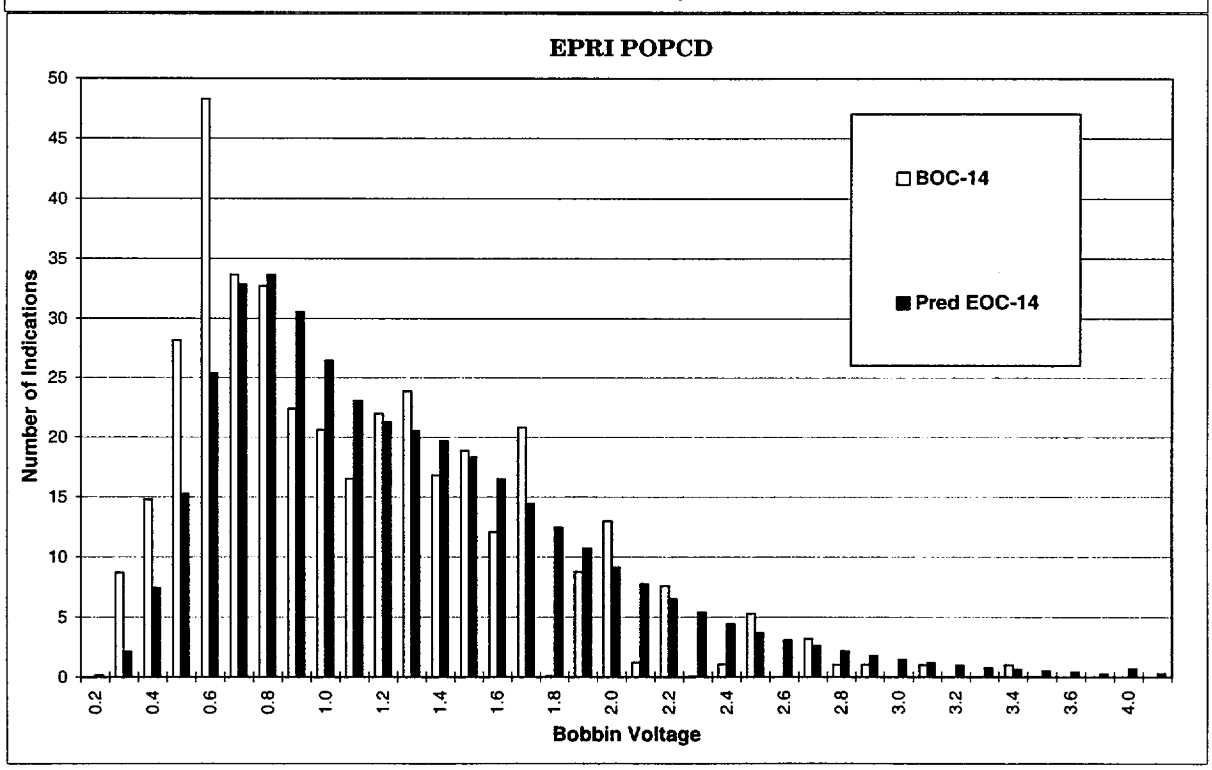
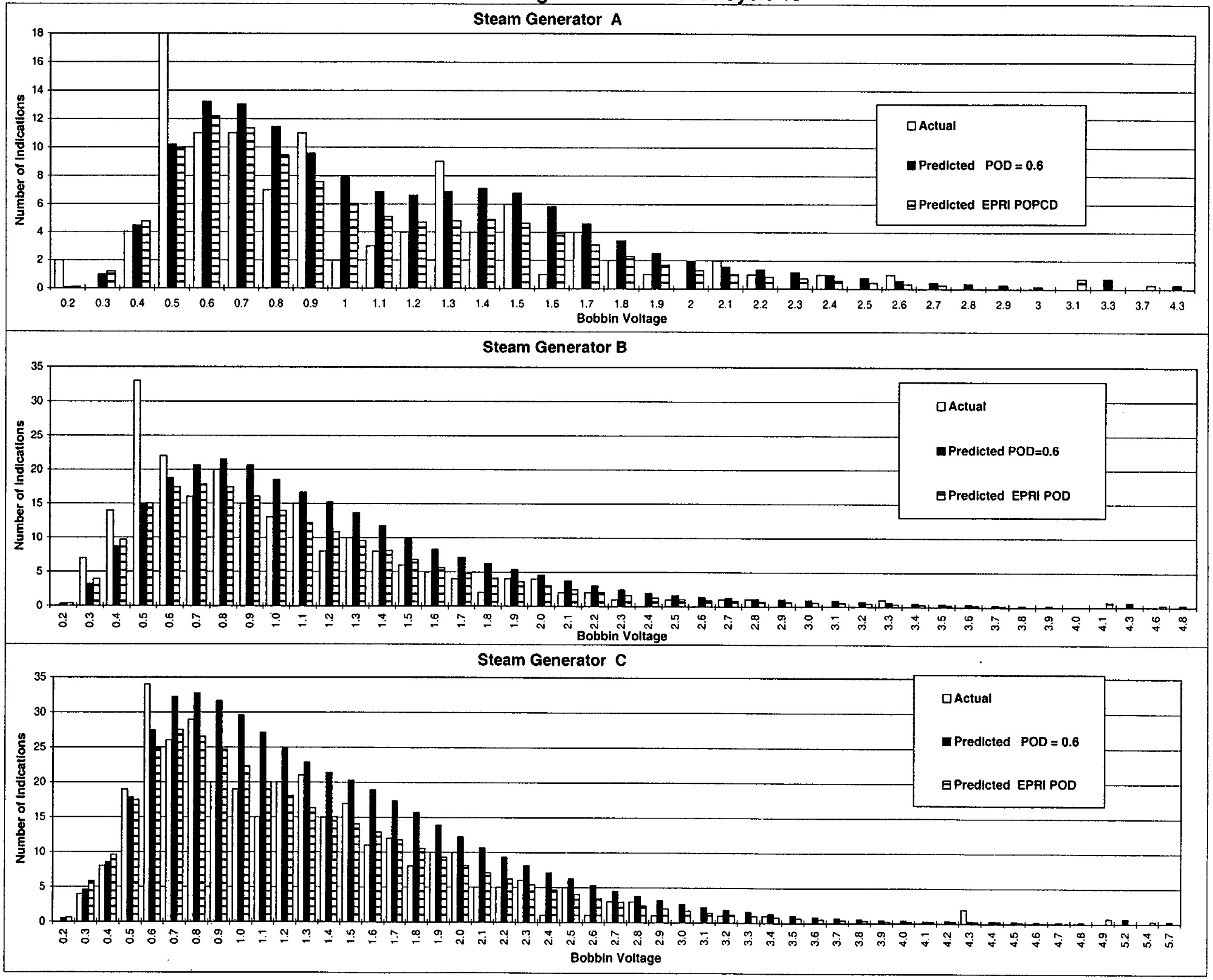


Figure 6-5
Farley Unit 2 October 1999
Bobbin Voltage Distributions for Cycle 13



Predcomp Fig_6 2/5/00 2:57 PM

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 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. The calculated leak rates are volumetric rates at room temperature and they should be compared with allowable leak rates at room temperature.

7.2 Predicted and Actual Leak Rate and Tube Burst Probability for EOC-13

Analyses were performed to calculate SLB tube leak rate and probability of burst for the actual bobbin voltage distribution at EOC-13 previously presented in this report. The results of Monte Carlo calculations performed based on the actual voltage distributions including NDE uncertainties are shown on Table 7-1. Projections for the EOC-13 conditions of all three SGs presented in the last 90-day report (Reference 8-4) are also included for comparison in Table 7-1. The allowable SLB rate for the last operating cycle (Cycle 13) was 11.8 gpm (at room temperature).

Comparisons of the EOC-13 actuals with the corresponding predictions indicate the following:

a) The actual number of indications found during EOC-13 inspection in all SGs are significantly below those projected during the last outage using POD=0.6, but slightly higher than that obtained with POPCD for SG-B. The peak voltages measured for all three SGs are lower than projected with both POD=0.6 as well as POPCD.

b) SG-C was projected to be the limiting steam generator for EOC-13 based on EOC-12 data, and it was confirmed to be limiting based on the actual bobbin measurements for EOC-13. For all SGs, SLB leak rates based on the actual voltage distributions are less than those projected with POD =0.6 as well as POPCD; they are also well below the acceptance limit (11.8 gpm at room temperature).

c) 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; they are also below the NRC reporting guideline of 10^{-2}.

d) SLB leak rates and burst probabilities reported originally in the last 90-day report are conservative.

In summary, the limiting SLB leak rate (1.1 gpm at room temperature) and tube burst probability (3.0×10^{-4}) calculated using the actual measured EOC-13 bobbin voltage distributions are well below the corresponding allowable limits (11.8 gpm and 10^{-2}, respectively). The results meet the requirement for continued operation.

7.3 Projected Leak Rate and Tube Burst Probability for EOC-14

Using the methodology previously described, calculations have been performed to predict the EOC-14 condition of all three steam generators in Farley Unit-2, and the results are summarized in Table 7-2. EOC-14 bobbin voltage distributions are predicted as well as the leak rates and tube burst probabilities based on these distributions. The leak rate vs. bobbin voltage correlation shown in Section 4.0 is applied. The projected leak rates are compared with the allowable leak rate at room temperature (11.8 gpm).

SG-C has both the highest number of indications as well as the largest indication returned to service for Cycle 14; therefore, it is projected to be the limiting SG. Since growth rate for Cycle 13 is more limiting than that for Cycle 12, Cycle 13 growth data were used in the EOC-14 projection analysis. The predicted EOC-14 SLB leak rate and burst probability for all three SGs are shown in Table 7-2. The limiting EOC-14 SLB leak rate predicted for SG-C based on constant POD of 0.6 is 2.2 gpm (room temperature), which is well below the licensed limit of 11.8 gpm at room temperature. The limiting EOC-14 burst probability (also predicted for SG-C with POD=0.6) is projected to be 4.4×10^{-4}; it is well below the NRC acceptance limit of 10^{-2}. Thus, the projected EOC-14 results meet the GL 95-05 requirement for continued operation.

In summary, SLB leak rates and tube burst probabilities projected for EOC-14 for all three SGs using the NRC-mandated POD = 0.6 meet the SER limits for Farley Unit-2. Results based on voltage dependent POPCD show even a greater margin between EOC-14 predictions and acceptance limits.

Table 7-1
Farley Unit 2 1999 EOC-13 Outage
Summary of Calculations of Tube Leak Rate and Burst Probability

Steam Generator	POD	Number of Indications(1)	Max. Volts	Burst Probability		SLB Leak Rate [gpm(2)]
				1 Tube	1 or More Tubes	
EOC – 13 PROJECTIONS(3)						
A	0.6	132	4.3	5.3×10^{-5}	5.3×10^{-5}	0.3
B		249	4.8	2.1×10^{-4}	2.1×10^{-4}	0.8
C		454	5.7	5.6×10^{-4}	5.6×10^{-4}	2.0
A	POPCD	104	3.7	5.8×10^{-5}	5.8×10^{-5}	0.2
B		195	4.6	1.7×10^{-4}	1.7×10^{-4}	0.5
C		345	5.4	3.7×10^{-4}	3.7×10^{-4}	1.4
EOC – 13 ACTUALS(4)						
A	1	105	2.6	5.3×10^{-5}	5.3×10^{-5}	0.2
B	1	215	3.3	6.8×10^{-5}	6.8×10^{-5}	0.4
C	1	332	4.3	2.9×10^{-4}	3.0×10^{-4}	1.1

Notes:
(1) Adjusted for POD.
(2) Equivalent volumetric rate at room temperature
(3) Based on leak and burst database presented in Reference 8-9 (Addendum-2 database).
(4) Based on leak and burst database presented in Reference 8-8 (Addendum-3 database).

Table 7-2
Farley Unit-2
Summary of Projected Tube Leak Rate and Burst Probability for EOC-14
(Based on a projected Cycle 14 length 430 EFPD)

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 8-8 Applied							
A(3)	0.6	172	3.4	7.3×10^{-5}	7.3×10^{-5}	0.4	Leak rate Correlation applied
B(3)		355	4.1	1.7×0^{-4}	1.7×10^{-4}	0.9	
C(4)		525	5.1	4.4×10^{-4}	4.4×10^{-4}	2.2	
A(3)	POPCD	138	3.2	5.3×10^{-5}	5.3×10^{-5}	0.3	
B(3)		287	3.9	1.3×10^{-4}	1.3×10^{-4}	0.7	
C(4)		385	4.2	2.3×10^{-4}	2.4×10^{-4}	1.4	

Notes

1. Number of indications adjusted for POD.
2. Volumetric leak rate adjusted to room temperature.
3. All SG composite growth rate distribution applied.
4. SG-C specific growth rate distribution 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. 115 to Facility Operating License NPF-8, Southern Nuclear Operating Company, Inc., Joseph M. Farley Nuclear Station, Unit 2, Docket No. 50-364", United States Nuclear Regulatory Commission, October 11,1996.

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-98-07-012, "Farley Unit-2 1998 Voltage Based Repair Criteria 90 Day Report," Westinghouse Nuclear Services Division, July 1998.

8-5 SG-97-03-001, "Farley Unit-2 1996 Alternate Repair Criteria 90 Day Report," Westinghouse Nuclear Services Division, March 1997.

8-6 SG-95-07-010, "Farley Unit-2, 1995 Interim Plugging Criteria 90 Day Report," Westinghouse Electric Corporation, July 1995.

8-7 WCAP-12871 Revision 2, "J. M. Farley Units 1 and 2 SG Tube Plugging Criteria for ODSCC at Tube Support Plates", Westinghouse Electric Corporation, Proprietary Class 2, February 1992.

8.8 Addendum-3 to EPRI Report NP-7480-L, "Steam Generator Outside Diameter Stress Corrosion Cracking at Tube Support Plates – Database for Alternate Repair Criteria," May 1999.

8-9 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.

8-10 Letter from B. W. Sheron, Nuclear Regulatory Commission, to A. Marion, Nuclear Energy Institute, dated February 9, 1996.

8-11 SG-99-08-04, "J. M. Farley Nuclear Plant Unit-2, Steam Generator Degradation Assessment 2R13 Refueling Outage," Westinghouse Electric Company, August 1999.