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SOUTH TEXAS UNIT-2

CYCLE 8 VOLTAGE-BASED REPAIR CRITERIA REPORT

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South Texas Unit-2
Cycle 8 Voltage-Based Repair Criteria Report

1.0 Introduction

This report provides a summary of the South Texas Unit-2 steam generator (SG) bobbin and rotating pancake coil (RPC) probe inspection at tube support plate (TSP) intersections, together with postulated steam line break (SLB) leak rate and tube burst probability analysis results, in support of continued implementation of a 1-volt repair criteria for Cycle 8 as outlined in the NRC Generic Letter 95-05 (Reference 8-1). A 1.0-volt repair criterion for outside diameter stress corrosion cracking (ODSCC) indications at the TSP intersections was implemented beginning with Cycle 7. Information required by Generic Letter (GL) 95-05 is provided in this report including SLB leak rates and tube burst probabilities calculated using the end of cycle (EOC) conditions for Cycle 7 and projection of bobbin voltage distributions, leak rates and burst probabilities for the EOC-8 conditions.

Analyses for Cycle 7 were carried out using the actual bobbin voltage data measured during the EOC-7 outage and the results compared with corresponding quantities from projections based on the EOC-6 bobbin voltage data presented in the last 90-day report (Reference 8-2). Westinghouse generic methodology based on Monte Carlo simulations presented in Reference 8-3 was used in these evaluations, and this methodology has been utilized for all prior GL 95-05 analyses for both South Texas units and is consistent with 1-volt repair criteria licensing-basis methodology.

Analyses were also performed to project leak rates and tube burst probabilities for postulated SLB conditions at the end of the ongoing cycle (Cycle 8) based on the 1.0 volt repair criteria. These analyses utilized bobbin voltage distributions measured during the recent (EOC-7) inspection and a limiting growth rate distribution from the last two inspections (EOC-6 and EOC-7 inspections).

Two other supplemental evaluations are also presented in this report. One of them examines the probability of detection for the EOC-6 inspection (probability of prior cycle detection – POPCD), and the other assesses the fraction of the indications that showed no degradation during the RPC inspection in 1998 (EOC-6 inspection), were left in service at beginning of Cycle 7 (BOC-7), and were RPC confirmed in 1999 at EOC-7.

2.0 Summary and Conclusions

A total of 2262 indications were found in the EOC-7 inspection, of which 160 are over 1 volt, 34 over 2 volts and 14 above 3 volts. A total of 177 indications were inspected with a RPC probe, including all 160 indications over 1 volt, and all but one indication were confirmed as flaws. The largest number of bobbin indications, 815 indications, were found in SG-B, but the largest number of indications exceeding 1 volt and 2 volts were in SG-C. Thus, SG-C is expected to be the limiting SG at EOC-8, which is also confirmed by analysis. No TSP indications were detected at the flow distribution baffle elevation, and only 2 TSP indications were detected on the cold leg side in this inspection, both at the top TSP in SG-C.

No RPC circumferential indications at the TSPs, no indications extending outside the TSPs, and no RPC indications with ID phase angles were found in this inspection. Also, no signal interference from copper deposits was found. A total of 55 TSP intersections in all 4 SGs combined with a mixed residual signal (MRI) that could potentially mask a 1.0 volt bobbin indication (MRI voltage 1.5 volts or greater) were inspected with a RPC probe and 3 of them were found to contain single axial indications (SAIs, one in SG-A and 2 in SG-C), and they were repaired. A total of 59 TSP intersections in all 4 SGs combined with a dent voltage greater than 5 volts were also inspected with a RPC probe; 2 intersections had a permeability variation signal (PVN), and no degradation was detected in the remaining 57 dents inspected. The tubes containing the dented intersections with a PVN signal (one each in SGs B and C) were repaired.

SLB leak rate and tube burst probability analyses were performed for the actual EOC-7 bobbin voltage distributions as well as the projected EOC-8 bobbin voltage distributions. The analysis took credit for the availability of pressurizer PORVs by using a primary-to-secondary pressure differential of 2405 psid for the design-basis SLB event. The SLB leak rate and tube burst probability results based on the actual measured EOC-7 voltage distributions were compared with those from the projections performed at BOC-7. The total number of indications found at TSPs during the current inspection in SGs B, C and D are less than those projected at the BOC-7 per the Generic Letter 95-05 requirements using a constant POD of 0.6 or a voltage-dependent POD, while the actual number of indications in SG-A exceeds its projection by about 12%. However, the total number of indications detected above 1 volt exceed the projections for all SGs except SG-A. Also, more indications over 2 volts were detected in all 4 SGs than projected (a total of 34 from all 4 SGs versus 10 projected). Growth rates during Cycle 7 were significantly higher than Cycle 6 growth rates in all SGs except SG-D. Since Cycle 6 growth rates were applied to project EOC-7 leak and burst

results, the leak rates and burst probability values based on the actual measured EOC-7 voltages are higher than the projections presented in the last 90-day report (Reference 8-2). However, leak rates and tube burst probabilities calculated using the actual measured voltages are about an order of magnitude below their respective allowable limits.

It is noted that while the EOC-7 projections utilized the leak and burst database presented in Addendum-2 to the EPRI database report (Reference 8-4), the latest database available then, the analysis for the actual EOC-7 conditions utilizes the updated Addendum-3 leak and burst database (Reference 8-5). The Addendum-3 database includes the latest (EOC-6) pulled tube leak and burst test data from South Texas Unit-2, and it was used for the EOC-7 analysis because it yields slightly more conservative results (by about 20% to 30%). However, the differences in the projected and actual EOC-7 leak rates and burst probabilities are higher than that attributable to the differences in the databases, i.e., EOC-7 projected values are underestimated because the actual growth rates during Cycle 7 were higher than those assumed in the projections. Growth rates for EOC-7 projections were selected in accordance with the GL 95-05 requirements. SG-A was predicted to be the limiting SG at EOC-7, but the actual EOC-7 leak and burst results for SGs B and C exceed those for SG-A. The underestimates between the projections for SG-A and the analysis based on the actuals for SG-C are about a factor of 3 for both SLB burst probability and leak rate based on the Database Addendum-3 correlations.

For the actual measured EOC-7 bobbin voltage distributions, the largest SLB leak rate is calculated for SG-C, and its magnitude is 0.14 gpm. This limiting leak rate is 2 orders of magnitude below the current allowable SLB leakage limit of 15.4 gpm. All leak rate values quoted are equivalent volumetric rates at room temperature. The corresponding conditional tube burst probability based on the actual EOC-7 voltage data for SG-C is 1.5×10^{-3}, which is nearly an order of magnitude below the NRC reporting guideline of 10^{-2}.

SLB leak rate and tube burst probability projections were also performed at the EOC-8 conditions for all 4 SGs. SG-C is predicted to be the limiting SG since it had the highest number of indications over 1 volt and over 2 volts at EOC-7. EOC-8 projections also utilized the leak and burst correlations based on the updated Addendum-3 leak and burst database available for 3/4" tubes (Reference 8-5). Cycle 7 growth data were used in the EOC-8 projection analysis, and the data show a dependency on the beginning of cycle voltage. Therefore, EOC-8 leak rates and tube burst probabilities for SGs A and C (SGs with the highest average Cycle 7 growth) were also calculated using the method recommended in Reference 8-4 to

account for voltage-dependent growth, in addition to the calculations based on the standard GL 95-05 method (Reference 8-3) which assumes growth rate is independent of the BOC voltage. In order to reduce excessive conservatism, the voltage-dependent POD distribution provided by POPCD (Reference 8-4) was applied with voltage-dependent growth, while the NRC mandated constant POD of 0.6 was used with the standard GL 95-05 method.

The limiting EOC-8 SLB leak rate is projected for SG-C, and its magnitude is 0.48 gpm based on the standard GL 95-05 methodology and 0.68 gpm using the voltage-dependent growth method. Both these leak rate values are more than a factor of 20 below the current licensed limit of 15.4 gpm. All leak rate values quoted are equivalent leak rates at room temperature. The corresponding EOC-8 tube burst probability values calculated for SG-C are 6.4×10^{-3} with the standard GL 95-05 methodology and 9.8×10^{-3} with the voltage-dependent growth. Both these burst probability estimates are below the NRC reporting guideline of 10^{-2}. Hence, the 1-volt repair criteria requirements for Cycle 8 operation are met.

Probability of detection (POPCD) for the EOC-6 inspection was assessed using EOC-6 and EOC-7 inspection data. The results support a detection probability greater than the NRC mandated value of 0.6. All 6 indications with no degradation found (NDF) by RPC during the EOC-6 inspection and returned to service for Cycle 7 were tested again in the EOC-7 inspection, and they were all confirmed yielding 100% RPC confirmation rate. Currently, the database for the RPC confirmation rate for prior cycle NDF indications in the South Texas units is too small to recommend a confirmation rate for use in the projection analyses. All RPC NDF indications are included in the EOC-8 projections presented in this report.

3.0 EOC-7 Inspection Results and Voltage Growth Rates

3.1 EOC-7 Inspection Results

According to the guidance provided by the NRC Generic Letter 95-05, the EOC-7 inspection of the South Texas Unit-2 SGs consisted of a complete, 100% eddy current (EC) bobbin probe examination of the tube support plate intersections in all four SGs. A 0.610 inch diameter probe was used for all hot and cold leg TSPs where voltage-based repair criterion was applied. RPC examination was performed for all indications with amplitude above 1 volt. As noted in the last 90-day report, 15 tubes in SG-D are excluded from voltage-based repair criteria as they are made of thermally treated tubes. Tubes in the wedge regions are not excluded from the 1-volt repair criteria as they are not expected to deform excessively under design-basis SLB conditions.

A summary of the EC results for the TSP indications in all four SGs is shown on Table 3-1, which tabulates the number of field bobbin indications, the number of those 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 8 operation is the difference between the observed and the ones removed from service.

Overall, the combined data for all four SGs of South Texas Unit-2 show the following.

- A total of 2262 TSP indications identified during the inspection of which 160 indications were over 1 volt and 34 over 2 volts. Only 2 indications were found on the cold side, both at the top TSP, with voltages less than or equal to 0.3 volts.

- All 160 indications over 1 volt were inspected with a RPC probe, all but one (1.2 volts) were confirmed as flaws. Seventeen additional indications ≤ 1 volt were also RPC inspected, and they were all confirmed.

- All 159 RPC-confirmed indications over 1 volt (bobbin) were repaired. Consistent with the 1 volt repair criteria, indications with bobbin amplitude less than or equal 1.0 volt (including the two on the cold leg side) were not considered for removal from service, regardless of RPC data.

No RPC circumferential indications at the TSPs, and no RPC indications with ID

phase angles were found in this inspection. There were no indications extending outside the TSPs or volumetric-type signals at the TSPs. Also, no signal interference from copper deposits was found. A total of 55 TSP intersections in all 4 SGs with a MRI signal that could potentially mask a 1.0 volt bobbin indication (MRI voltage 1.5 volts or greater) were inspected with a RPC probe and 3 of them were found to contain SAIs (one in SG-A and 2 in SG-C), and they were repaired. A total of 59 TSP intersections in all 4 SGs combined with a dent voltage greater than 5 volts were also inspected with a RPC probe; 2 intersections had a PVN signal, and no degradation was detected in the remaining 57 dents inspected. The tubes containing the dented intersections with PVN signals (one each in SGs B and C) were repaired.

A review of Table 3-1 indicates that more indications (a total of 751) are returned to service for Cycle 8 in SG-B, than in the other 3 SGs. However, since SG-C had the largest number of indications over 1 volt and over 2 volts at EOC-7 (48 and 11 indications, respectively), and 2/3^{rds} of every repaired indication is treated as still active in the analysis based on constant POD=0.6, SG-C is expected to be the limiting SG at EOC-8, which is confirmed by analysis.

Figure 3-1 shows the actual bobbin voltage distribution determined from the EOC-7 EC inspection; Figure 3-2 shows the population distribution of those EOC-7 indications removed from service due to tube repairs; Figure 3-3 shows the distribution for indications returned to service for Cycle 8. Of the 247 indications removed from service, 162 indications are in tubes repaired because of the TSP voltage-based repair criteria including the 3 RPC indications found in MRIs. The rest are in tubes plugged for degradation mechanisms other than ODSCC at TSPs.

The distribution of EOC-7 indications as a function of support plate location is summarized in Table 3-2 and plotted in Figure 3-4. The data show a strong predisposition of ODSCC to occur in the first few hot leg TSPs (2094 out of 2262 or about 93% of the indications occurred at hot leg intersections in the first three TSP above the flow distribution baffle plate), although the mechanism extended to higher TSPs. Only two indications were detected on the cold leg side (both in SG-C). In summary, the distribution of indication population at TSPs in South Texas Unit-2 show the predominant temperature dependence of ODSCC, similar to that observed at other plants.

3.2 Voltage Growth Rates

For projection of leak rates and tube burst probabilities at the end of Cycle 8

operation, voltage growth rates were developed from EOC-7 inspection data and a reevaluation of the EOC-6 inspection EC signals for the same indications. Table 3-3 shows the cumulative probability distribution (CPDF) for growth rate in each South Texas Unit-2 steam generator during Cycle 7 (October '98 - October '99) on an EFPY basis, along with the corresponding Cycle 6 growth rate distributions. Cycle 7 growth data are also plotted in Figure 3-5. The curve labelled 'cumulative' in Figure 3-5 represents composite growth data from all four SGs.

Average growth rates for each SG during Cycle 7 are summarized in Table 3-4. The average growth rates for all SGs over the entire voltage range vary between 38.4% to 52.3% per EFPY; however, the magnitude of average growth in all SGs is relatively small (less than 0.25 volts/EFPY). Among the four steam generators, both SGs A and C had the highest average voltage growth for Cycle 7 (52.3%/EFPY), but SG-C had 3 out of the 5 largest voltage growth during Cycle 7 (see Table 3-3), and the remaining 2 were in SG-B. Thus, SG-C has the limiting growth rate distribution for Cycle 7. The average growth for all indications greater than or equal to 0.75 volt is 41.8%/EFPY versus 45.9%/EFPY for indications less than 0.75 volt. A smaller average growth for indications ≥ 0.75 volt is not consistent with the data for other plants; however, the difference between the two growth rates are not significant. The larger growth rates found in SG-C is reflected in the 74.1%/EFPY average growth for BOC indications > 0.75 volt.

Averaged composite voltage growth data from all four SGs for the last three operating periods are summarized in Table 3-5. The principal difference between Cycle 7 and previous cycles is the larger average growth rate (41.8%/EFPY) for BOC indications >0.75 volt. Figure 3-6 shows the CPDFs for the last two cycles growth data. The guidelines in Generic Letter 95-05 require the use of the more conservative growth rate distribution from the past two inspections for projecting EOC distributions for the next operating cycle. It is clearly evident that the growth rates during Cycle 7 are higher than in Cycle 6. Hence, Cycle 7 growth distribution was applied to obtain SLB leak rate and tube burst probability projections for the EOC-8 conditions.

From Table 3-3 and Figure 3-5 it is evident that the Cycle 7 growth rates for SG-C are higher than the composite growth data. Per the methodology described in Reference 8-3, SG-specific growth rates are to be used for SG-C. The Cycle 7 growth distribution for SG-A is slightly higher than the composite growth distribution up to 3 volts growth, but it do not include the top 5 growth values (all above 3 volts) observed for Cycle 7. Therefore, leak and burst projections for SG-A

were performed using both its own growth distribution as well as the composite growth and the limiting result is presented. Composite growth rates were applied for the other two SGs (SGs B and D).

Figure 3-7 is a plot of voltage growth during Cycle 7 vs. BOC-7 voltage for all 4 SGs. An examination of Figure 3-7 indicates that the Cycle 7 growth data show a dependency on BOC-6 voltage since a greater fraction of indications over 0.5 volts show growth over 1 volt than indications under 0.5 volts. As a sensitivity study, EOC-8 leak rate and burst probability projections for SGs A and C (SGs with the highest average Cycle 7 growth) were also repeated taking into account the growth dependency on the BOC voltage in accordance with the methodology recommended in Reference 8-4 for considering growth dependency on BOC voltage, and the results are discussed in Section 7.0.

It is evident from Figure 3-7 that a number of indications had a relatively large voltage growth (in excess of 2 volts) during Cycle 7. This growth behavior was unexpected and may be a one time event. To examine the impact of this growth trend continuing in Cycle 8, additional sensitivity analyses were performed for EOC-8 leak rates and burst probabilities using more conservative growth distributions. Since relatively high growth values observed during a cycle can be expected to occur randomly in any SG, all 4 SGs have the same likelihood of experiencing the highest growth for the ongoing cycle. Therefore, a composite growth distribution composed of SG-specific Cycle 7 growth data plus the top 3 growth values for Cycle 7 (if they are not already part of the SG-specific growth data) were applied to project EOC-8 conditions for each SG.

Table 3-6 lists the top 30 indications on the basis of Cycle 7 growth rates in descending order. All of those indications were RPC confirmed and only 7 of them are new indications. The EOC-6 voltages used to estimate growth rates for the new indications were obtained by reevaluating the prior inspection data.

3.3 NDE Uncertainties

The NDE uncertainties applied for the Cycle 7 voltage distributions in the Monte Carlo analyses for leak rate and burst probabilities are the same as those used for the last GL 95-05 evaluation reported in Reference 8-2. They are presented in Table 3-7 as well as graphically illustrated in Figure 3-8. 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 10.3% about a mean of zero

with no cutoff. These NDE uncertainty distributions are included in the Monte Carlo analyses for SLB leak rates and tube burst probabilities based on the EOC-7 actual voltage distributions as well as for the EOC-8 projections.

3.4 Probability of Prior Cycle Detection (POPCD)

The inspection results at EOC-7 permit an evaluation of the probability of detection (POD) at the prior EOC-6 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 voltage-based repair criteria 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-7 inspection can then be defined as follows.

$$\text{POPCD (EOC-6)} = \frac{\text{EOC-6 cycle reported indications confirmed by RPC in EOC-7 inspection} + \text{Indications confirmed and repaired in EOC-6 inspection}}{\{\text{Numerator}\} + \text{New indications RPC confirmed in EOC-7 inspection}}$$

POPCD is evaluated at the 1998 EOC-6 voltage values (from 1999 reevaluation for growth rate) since it is an EOC-6 POPCD assessment. The indications detected at EOC-6 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-7. 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-7 indications not reported in the EOC-6 inspection. The new indications include EOC-6 indications present at detectable levels but not reported, indications present at EOC-6 below detectable levels and indications that initiated during Cycle 7. 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-6 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-7 indications not RPC inspected since inclusion for the EOC-6 inspection for repaired tube could increase POPCD by including indications on a tube plugged for non-ODSCC causes which could be RPC NDF indications. In addition, the objective of using RPC confirmation for POPCD is to distinguish detection of 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-7 RPC confirmed by RPC confirmed plus not RPC inspected in the above definition of POPCD. For this report, both POPCD definitions are evaluated for South Texas Unit-2.

It can be noted that many of the new indications not RPC inspected can be false calls and are not found at the subsequent inspection. It would be appropriate to define new indications as the net increase in new indications at EOC-7 minus indications reported at EOC-6, but not found at EOC-7. This would represent the net new number of unconfirmed indications. Ignoring this effect leads to conservative POPCD distribution.

The POPCD evaluation for the 1998 EOC-6 inspection data is summarized in Table 3-8 and illustrated on Figure 3-9. It is evident that South Texas Unit-2 POPCD values support a POD significantly higher than the NRC mandated value of 0.6. A generic POPCD distribution developed by analyses of 25 inspections in 12 plants and presented in Table 7-4 of Reference 8-5 is also shown in Figure 3-9. It is seen from Figure 3-9 that the POPCD values for South Texas Unit-2 are comparable to the generic POPCD in the voltage range 0.2 to 0.6 volt, and between 0.6 to 1.5 volts it is slightly below the generic data. The South Texas Unit-2 POPCD value reaches unity at about 1.5 volts where as the generic POPCD is unity at 3.5 volts.

In summary, the South Texas Unit-2 EOC-7 POPCD supports a POD higher than the NRC mandated POD value of 0.6.

3.5 Assessment of RPC Confirmation Rates

This section tracks the 1998 EOC-6 indications left in service at BOC-7 relative to RPC inspection results in 1999 at EOC-7. If sufficient plant-specific data is available on RPC confirmation rates for prior cycle NDFs, NRC approval may be obtained for considering only a fraction of unconfirmed (RPC NDF) indications in

the BOC voltage distributions used for SLB leak rate and tube burst probability projections.

The composite results from this evaluation for all 4 SGs are given in Table 3-9. For EOC-6 bobbin indications left in service, the indications are tracked relative to EOC-7 RPC confirmed, EOC-7 RPC NDF, EOC-7 bobbin indications not RPC inspected, and EOC-6 bobbin indications with no indication found in EOC-7. Also included are new EOC-7 indications. The table shows, for each category of indications, the number of indications RPC inspected and RPC confirmed in EOC-7, as well as the percentage of RPC confirmed indications.

All 6 EOC-6 RPC NDF indications in service at BOC-7 were RPC tested during the EOC-7 inspection, and all were confirmed. Therefore, the RPC confirmation rate for prior RPC NDF indications is 100%. However, RPC NDF database for South Texas Unit-2 is still too small to recommend a confirmation rate for use in the projection analyses. All RPC NDF indications are included in the EOC-8 projections presented in Section 7.0.

3.6 Probe Wear Criteria

An alternate probe wear criteria approved by the NRC (Reference 8-6) was applied during the EOC-7 inspection. When a probe does not pass the 15% wear limit, this alternate criteria requires that only tubes with indications above 75% of the repair limit since the last successful probe wear check be reinspected with a good probe. As the repair limit is 1 volt, all tubes containing indications for which the worn probe voltage was above 0.75 volt 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 8-6, 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 indications were detected with new probes; thus, worn probes did not miss any indication. Figure 3-10 shows plots of the worn probe voltages plotted against the new probe voltages for all 4 SGs, and the majority data points are above the 45° line shown, indicating the worn probe voltages were higher than the new probe voltages. There are only 2 indications for which the new probe voltage exceeds worn voltage by more than 20%, and both these indications had a new probe voltage under 0.65 volts.

Composite data from all 4 SGs are plotted in Figure 3-11. Also shown in the figure

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 slightly greater than 45° slope indicating that on the average new probe voltages are slightly less than the worn probe voltages. The dotted horizontal line at 0.75 worn probe volts demarcates indications requiring retest from those that do not. The shaded area at the bottom above 1 volt (on abscissa) shows the region where a tube requiring repair may be left in service because of probe wear. In the South Texas Unit-2 EOC-7 inspection, there are no occurrences for which a worn probe was less than 0.75 volt and the new probe voltage exceeded the plugging limit, i.e., no pluggable tubes were missed due to probe wear considerations.

Among all the indications in tubes retested, only 5 indications fall outside both the 90%/95% tolerance limit bands and ±25% of the new probe voltage bands. Four of these indications lie above the upper 90%/95% tolerance band as well as the upper 25% band; i.e., the worn probe voltages are higher than the corresponding new probe voltages and the worn probe voltages are conservative. Therefore, the data for these 4 indications are acceptable. The only indication lying below the lower 90%/95% tolerance line has a bobbin voltage <0.65 volt with the new probe, and a voltage variation of few tenths of a volt can be expected for such an indication if the measurement is repeated with new or worn probes. Therefore, the data for 5 indications outside the 90%/95% tolerance bands 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-7 inspection is consistent with the NRC guidance provided in Reference 8-6.

Table 3-1 (Sheet 1 of 2)
South Texas Unit 2 October 99 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 7

Voltage Bin	Steam Generator A						Steam Generator B						Steam Generator C					
	In-Service During Cycle 7				RTS for Cycle 8		In-Service During Cycle 7				RTS for Cycle 8		In-Service During Cycle 7				RTS for Cycle 8	
	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	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.2	3	0	0	0	3	3	13	0	0	0	13	13	12	0	0	0	12	12
0.3	24	0	0	0	24	24	94	0	0	2	92	92	54	0	0	2	52	52
0.4	58	0	0	2	56	56	185	0	0	3	182	182	104	0	0	9	95	95
0.5	64	0	0	1	63	63	170	0	0	2	168	168	118	0	0	7	111	111
0.6	49	0	0	1	48	48	133	4	4	9	124	124	106	0	0	3	103	103
0.7	41	0	0	3	38	38	73	0	0	2	71	71	68	0	0	1	67	67
0.8	23	0	0	1	22	22	52	1	1	3	49	49	44	0	0	2	42	42
0.9	25	0	0	0	25	25	35	2	2	2	33	33	24	0	0	3	21	21
1	10	0	0	0	10	10	23	2	2	5	18	18	24	1	1	1	23	23
1.1	9	9	9	9	0	0	11	11	11	11	0	0	16	16	16	16	0	0
1.2	6	6	6	6	0	0	5	5	4	4	1	0	5	5	5	5	0	0
1.3	2	2	2	2	0	0	3	3	3	3	0	0	3	3	3	3	0	0
1.4	1	1	1	1	0	0	3	3	3	3	0	0	5	5	5	5	0	0
1.5	2	2	2	2	0	0	2	2	2	2	0	0	2	2	2	2	0	0
1.6	1	1	1	1	0	0	0	0	0	0	0	0	2	2	2	2	0	0
1.7	2	2	2	2	0	0	1	1	1	1	0	0	0	0	0	0	0	0
1.8	2	2	2	2	0	0	1	1	1	1	0	0	3	3	3	3	0	0
1.9	1	1	1	1	0	0	3	3	3	3	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
2.1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0
2.2	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0
2.3	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0
2.4	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0
2.5	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0
2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.8	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	1	1	1	1	0	0	2	2	2	2	0	0
3.1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
3.3	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0
3.4	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0
3.6	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.9	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
4.2	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0
4.8	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
Total	330	33	33	41	289	289	815	46	45	64	751	750	602	49	49	76	526	526
>1v	33	33	33	33	0	0	37	37	36	36	1	0	48	48	48	48	0	0

Table 3-1 (Sheet 2 of 2)
South Texas Unit 2 October 99 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 7

Voltage Bin	Steam Generator D						Composite of All SGs					
	In-Service During Cycle 7				RTS for Cycle 8		In-Service During Cycle 7				RTS for Cycle 8	
	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	7	0	0	0	7	7	35	0	0	0	35	35
0.3	50	0	0	3	47	47	222	0	0	7	215	215
0.4	119	1	1	2	117	117	466	1	1	16	450	450
0.5	97	0	0	4	93	93	449	0	0	14	435	435
0.6	85	2	2	7	78	78	373	6	6	20	353	353
0.7	51	0	0	3	48	48	233	0	0	9	224	224
0.8	36	3	3	3	33	33	155	4	4	9	146	146
0.9	18	1	1	2	16	16	102	3	3	7	95	95
1	10	0	0	0	10	10	67	3	3	6	61	61
1.1	10	10	10	10	0	0	46	46	46	46	0	0
1.2	5	5	5	5	0	0	21	21	20	20	1	0
1.3	5	5	5	5	0	0	13	13	13	13	0	0
1.4	8	8	8	8	0	0	17	17	17	17	0	0
1.5	3	3	3	3	0	0	9	9	9	9	0	0
1.6	0	0	0	0	0	0	3	3	3	3	0	0
1.7	0	0	0	0	0	0	3	3	3	3	0	0
1.8	0	0	0	0	0	0	6	6	6	6	0	0
1.9	2	2	2	2	0	0	6	6	6	6	0	0
2	1	1	1	1	0	0	2	2	2	2	0	0
2.1	2	2	2	2	0	0	4	4	4	4	0	0
2.2	1	1	1	1	0	0	3	3	3	3	0	0
2.3	2	2	2	2	0	0	4	4	4	4	0	0
2.4	0	0	0	0	0	0	2	2	2	2	0	0
2.5	0	0	0	0	0	0	2	2	2	2	0	0
2.6	1	1	1	1	0	0	1	1	1	1	0	0
2.8	0	0	0	0	0	0	1	1	1	1	0	0
3	0	0	0	0	0	0	3	3	3	3	0	0
3.1	0	0	0	0	0	0	1	1	1	1	0	0
3.3	0	0	0	0	0	0	2	2	2	2	0	0
3.4	1	1	1	1	0	0	2	2	2	2	0	0
3.5	0	0	0	0	0	0	2	2	2	2	0	0
3.6	0	0	0	0	0	0	1	1	1	1	0	0
3.7	1	1	1	1	0	0	1	1	1	1	0	0
3.9	0	0	0	0	0	0	1	1	1	1	0	0
4	0	0	0	0	0	0	1	1	1	1	0	0
4.2	0	0	0	0	0	0	2	2	2	2	0	0
4.8	0	0	0	0	0	0	1	1	1	1	0	0
Total	515	49	49	66	449	449	2262	177	176	247	2015	2014
>1v	42	42	42	42	0	0	160	160	159	159	1	0

Table 3-2
South Texas Unit 2 October 1999
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 7

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
02H	154	3.59	0.69	2.77	0.27	315	4.19	0.59	3.81	0.19
03H	121	3.28	0.66	2.65	0.19	280	2.92	0.54	2.27	0.13
04H	39	1.06	0.49	0.42	0.11	166	1.04	0.47	0.52	0.09
05H	16	0.78	0.45	0.39	0.10	50	0.94	0.46	0.41	0.11
06H	0	-	-	-	-	4	1.26	0.64	0.29	0.12
07H	0	-	-	-	-	0	-	-	-	-
08H	0	-	-	-	-	0	-	-	-	-
11C	0	-	-	-	-	0	-	-	-	-
Total	330					815				

Tube Support Plate	Steam Generator C					Steam Generator D				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
02H	232	3.48	0.68	2.76	0.25	258	3.37	0.57	2.70	0.17
03H	183	4.11	0.59	3.51	0.19	183	3.69	0.63	2.70	0.18
04H	126	4.78	0.56	3.84	0.17	37	1.10	0.52	0.44	0.14
05H	37	1.17	0.52	0.44	0.13	23	0.85	0.49	0.35	0.11
06H	18	1.05	0.50	0.27	0.10	13	0.71	0.39	0.16	0.06
07H	3	0.64	0.44	0.20	0.17	1	0.32	0.32	0.03	0.03
08H	1	0.37	0.37	0.08	0.08	0	-	-	-	-
11C	2	0.30	0.25	0.05	0.04	0	-	-	-	-
Total	602					515				

Table 3-3
South Texas Unit 2 October 99
Signal Growth Statistics For Cycle 7 on an EFPY Basis

Delta Volts	Steam Generator A			Steam Generator B			Steam Generator C			Steam Generator D			Cumulative		
	Cycle 6	Cycle 7		Cycle 6	Cycle 7		Cycle 6	Cycle 7		Cycle 6	Cycle 7		Cycle 6	Cycle 7	
	CPDF#	No. of Inds	CPDF#	CPDF#	No. of Inds	CPDF#	CPDF#	No. of Inds	CPDF#	CPDF#	No. of Inds	CPDF#	CPDF#	No. of Inds	CPDF#
-0.4	0.0	0	0.0	0.0	2	0.002	0.0	0	0.0	0.0	0	0.0		2	0.001
-0.2	0.005	0	0.0	0.002	2	0.005	0.0	0	0.0	0.0	0	0.0	0.001	2	0.002
-0.1	0.032	2	0.006	0.002	13	0.021	0.004	5	0.008	0.0	6	0.012	0.006	26	0.013
0	0.266	26	0.085	0.132	94	0.136	0.112	31	0.06	0.041	51	0.111	0.122	202	0.103
0.1	0.782	90	0.358	0.8	280	0.48	0.746	205	0.4	0.541	197	0.493	0.722	772	0.444
0.2	0.926	109	0.688	0.966	269	0.81	0.952	195	0.724	0.847	136	0.757	0.929	709	0.757
0.3	0.947	43	0.818	0.996	79	0.907	0.987	73	0.846	0.947	57	0.868	0.976	252	0.869
0.4	0.963	20	0.879	0.996	36	0.951	0.989	36	0.905	0.971	28	0.922	0.984	120	0.922
0.5	0.973	15	0.924	1.0	14	0.968	0.991	18	0.935	0.988	7	0.936	0.991	54	0.946
0.6	0.979	8	0.948	1.0	5	0.974	0.991	9	0.95	0.991	6	0.948	0.993	28	0.958
0.7	0.979	5	0.964	1.0	3	0.978	0.993	7	0.962	0.994	5	0.957	0.994	20	0.967
0.8	0.979	1	0.967	1.0	2	0.98	0.996	1	0.963	0.997	2	0.961	0.995	6	0.969
0.9	0.979	3	0.976	1.0	0	0.98	0.996	4	0.97	0.997	2	0.965	0.995	9	0.973
1	0.979	0	0.976	1.0	1	0.982	0.998	2	0.973	1.0	5	0.975	0.997	8	0.977
1.1	0.989	0	0.976	1.0	1	0.983	0.998	2	0.977	1.0	2	0.979	0.998	5	0.979
1.2	0.989	0	0.976	1.0	1	0.984	1.0	1	0.978	1.0	0	0.979	0.999	2	0.98
1.3	0.989	0	0.976	1.0	2	0.987	1.0	1	0.98	1.0	1	0.981	0.999	4	0.982
1.4	0.989	1	0.979	1.0	1	0.988	1.0	0	0.98	1.0	1	0.983	0.999	3	0.983
1.5	0.995	0	0.979	1.0	1	0.989	1.0	2	0.983	1.0	4	0.99	0.999	7	0.986
1.6	0.995	1	0.982	1.0	1	0.99	1.0	0	0.983	1.0	2	0.994	0.999	4	0.988
1.7	0.995	0	0.982	1.0	2	0.993	1.0	0	0.983	1.0	0	0.994	0.999	2	0.989
1.8	0.995	1	0.985	1.0	1	0.994	1.0	0	0.983	1.0	0	0.994	0.999	2	0.99
1.9	0.995	0	0.985	1.0	0	0.994	1.0	2	0.987	1.0	0	0.994	0.999	2	0.991
2.1	0.995	0	0.985	1.0	1	0.995	1.0	0	0.987	1.0	1	0.996	0.999	2	0.992
2.2	1.0	1	0.988	1.0	0	0.995	1.0	2	0.99	1.0	0	0.996	1.0	3	0.993
2.3	1.0	0	0.988	1.0	0	0.995	1.0	1	0.992	1.0	0	0.996	1.0	1	0.993
2.5	1.0	0	0.988	1.0	1	0.996	1.0	0	0.992	1.0	0	0.996	1.0	1	0.994
2.7	1.0	0	0.988	1.0	1	0.998	1.0	0	0.992	1.0	0	0.996	1.0	1	0.994
2.8	1.0	2	0.994	1.0	0	0.998	1.0	1	0.993	1.0	0	0.996	1.0	3	0.996
2.9	1.0	1	0.997	1.0	0	0.998	1.0	0	0.993	1.0	2	1.0	1.0	3	0.997
3	1.0	1	1.0	1.0	0	0.998	1.0	1	0.995	1.0	0	1.0	1.0	2	0.998
3.4	1.0	0	1.0	1.0	1	0.999	1.0	1	0.997	1.0	0	1.0	1.0	2	0.999
3.8	1.0	0	1.0	1.0	0	0.999	1.0	1	0.998	1.0	0	1.0	1.0	1	0.999
4.1	1.0	0	1.0	1.0	1	1.0	1.0	1	1.0	1.0	0	1.0	1.0	2	1.0
Total		330			815			602			515			2262	

Cumulative probability density

Table 3-4
South Texas Unit 2 - October 1999 Outage
Average Voltage Growth During Cycle 7

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	2262	0.41	0.174	0.185	42.6%	45.4%
$V_{BOC} <$ .75 Volts	2141	0.38	0.164	0.175	43.0%	45.9%
≥ .75 Volts	121	0.89	0.348	0.371	39.2%	41.8%
	Steam Generator A					
Entire Voltage Range	330	0.43	0.211	0.226	49.1%	52.3%
$V_{BOC} <$ .75 Volts	301	0.38	0.193	0.206	50.1%	53.5%
≥ .75 Volts	29	0.91	0.406	0.433	44.4%	47.4%
	Steam Generator B					
Entire Voltage Range	815	0.40	0.143	0.153	36.0%	38.4%
$V_{BOC} <$ .75 Volts	778	0.38	0.146	0.155	38.8%	41.4%
≥ .75 Volts	37	0.86	0.091	0.097	10.5%	11.3%
	Steam Generator C					
Entire Voltage Range	602	0.41	0.201	0.214	49.1%	52.3%
$V_{BOC} <$ .75 Volts	576	0.39	0.182	0.194	47.0%	50.1%
≥ .75 Volts	26	0.90	0.622	0.663	69.5%	74.1%
	Steam Generator D					
Entire Voltage Range	515	0.41	0.166	0.177	40.5%	43.2%
$V_{BOC} <$ .75 Volts	486	0.38	0.154	0.164	40.3%	43.0%
≥ .75 Volts	29	0.89	0.371	0.396	41.8%	44.6%

Based on Cycle 7 duration of 342.5 EFPD (0.938 EFPY)

Table 3-5
South Texas 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 7 (1998 - 1999) - 342.5 EFPD					
Entire Voltage Range	2262	0.41	0.174	0.185	42.6%	45.4%
$V_{BOC} <$ .75 Volts	2141	0.38	0.164	0.175	43.0%	45.9%
≥ .75 Volts	121	0.89	0.348	0.371	39.2%	41.8%
	Cycle 6 (1997 - 1998) - 564.9 EFPD					
Entire Voltage Range	1484	0.31	0.13	0.08	42%	27%
$V_{BOC} <$ .75 Volts	1437	0.29	0.13	0.08	44%	29%
≥ .75 Volts	47	0.93	0.16	0.10	17%	11%
	Cycle 5 (1995 - 1997) - 450 EFPD					
Entire Voltage Range	703	0.31	0.12	0.10	39%	31%
$V_{BOC} <$ .75 Volts	696	0.31	0.12	0.10	39%	32%
≥ .75 Volts	7	0.91	0.20	0.16	22%	18%

Table 3-6
South Texas Unit 2 October 1999
Summary of Largest Voltage Growth Rates for BOC-7 to EOC-7

Steam Generator				Bobbin Voltage			RPC	New
SG	Row	Col	Elevation	EOC	BOC	Growth	Confirmed ?	Indication ?
C	31	50	04H	4.78	0.94	3.84	Y	N
B	18	43	02H	4.19	0.38	3.81	Y	N
C	23	38	03H	4.11	0.6	3.51	Y	N
B	26	52	02H	3.84	0.65	3.19	Y	N
C	21	74	03H	3.97	0.84	3.13	Y	N
A	11	26	02H	3.44	0.67	2.77	Y	Y
C	20	82	02H	3.48	0.72	2.76	Y	N
D	23	45	02H	3.37	0.67	2.7	Y	N
D	29	43	03H	3.69	0.99	2.7	Y	N
A	24	88	03H	3.28	0.63	2.65	Y	N
C	23	74	03H	3.25	0.62	2.63	Y	Y
A	20	41	02H	3.59	0.98	2.61	Y	N
A	44	68	02H	3.31	0.74	2.57	Y	N
B	18	51	02H	3.03	0.53	2.5	Y	N
B	30	53	03H	2.92	0.65	2.27	Y	N
C	11	103	02H	2.97	0.88	2.09	Y	N
C	41	68	02H	2.98	0.96	2.02	Y	N
A	23	94	02H	2.77	0.76	2.01	Y	Y
C	23	74	02H	2.45	0.46	1.99	Y	N
D	33	52	03H	2.51	0.61	1.9	Y	N
B	11	34	02H	2.49	0.6	1.89	Y	N
C	19	75	02H	2.4	0.62	1.78	Y	Y
C	10	113	02H	2.32	0.57	1.75	Y	N
B	41	73	02H	2.18	0.54	1.64	Y	Y
A	20	78	02H	2.09	0.46	1.63	Y	N
B	17	111	03H	2.24	0.7	1.54	Y	N
B	7	24	02H	2.07	0.55	1.52	Y	N
D	19	106	02H	2.19	0.69	1.5	Y	N
A	23	41	02H	1.67	0.19	1.48	Y	Y
B	10	33	02H	1.82	0.38	1.44	Y	Y

Table 3-7
Probe Wear and Analyst Variability - Tabulated Values

Analyst Variability Std. Dev = 10.3% Mean = 0.0% No Cutoff	
Value	Cumul. Prob.
-40.0%	0.00005
-38.0%	0.00011
-36.0%	0.00024
-34.0%	0.00048
-32.0%	0.00095
-30.0%	0.00179
-28.0%	0.00328
-26.0%	0.00580
-24.0%	0.00990
-22.0%	0.01634
-20.0%	0.02608
-18.0%	0.04027
-16.0%	0.06016
-14.0%	0.08704
-12.0%	0.12200
-10.0%	0.16581
-8.0%	0.21867
-6.0%	0.28011
-4.0%	0.34888
-2.0%	0.42302
0.0%	0.50000
2.0%	0.57698
4.0%	0.65112
6.0%	0.71989
8.0%	0.78133
10.0%	0.83419
12.0%	0.87800
14.0%	0.91296
16.0%	0.93984
18.0%	0.95973
20.0%	0.97392
22.0%	0.98366
24.0%	0.99010
26.0%	0.99420
28.0%	0.99672
30.0%	0.99821
32.0%	0.99905
34.0%	0.99952
36.0%	0.99976
38.0%	0.99989
40.0%	0.99995

Probe Wear Variability Std. Dev = 7.0% Mean = 0.0% Cutoff at +/- 15%	
Value	Cumul. Prob.
< -15.0%	0.00000
-15.0%	0.01606
-14.0%	0.02275
-13.0%	0.03165
-12.0%	0.04324
-11.0%	0.05804
-10.0%	0.07656
-9.0%	0.09927
-8.0%	0.12655
-7.0%	0.15866
-6.0%	0.19568
-5.0%	0.23753
-4.0%	0.28385
-3.0%	0.33412
-2.0%	0.38755
-1.0%	0.44320
0.0%	0.50000
1.0%	0.55680
2.0%	0.61245
3.0%	0.66588
4.0%	0.71615
5.0%	0.76247
6.0%	0.80432
7.0%	0.84134
8.0%	0.87345
9.0%	0.90073
10.0%	0.92344
11.0%	0.94196
12.0%	0.95676
13.0%	0.96835
14.0%	0.97725
15.0%	0.98394
> 15.0%	1.00000

Table 3-8
South Texas Unit 2 1999 EOC-7 Evaluation for Probability of Prior Cycle Detection
Composite of All Steam Generator Data

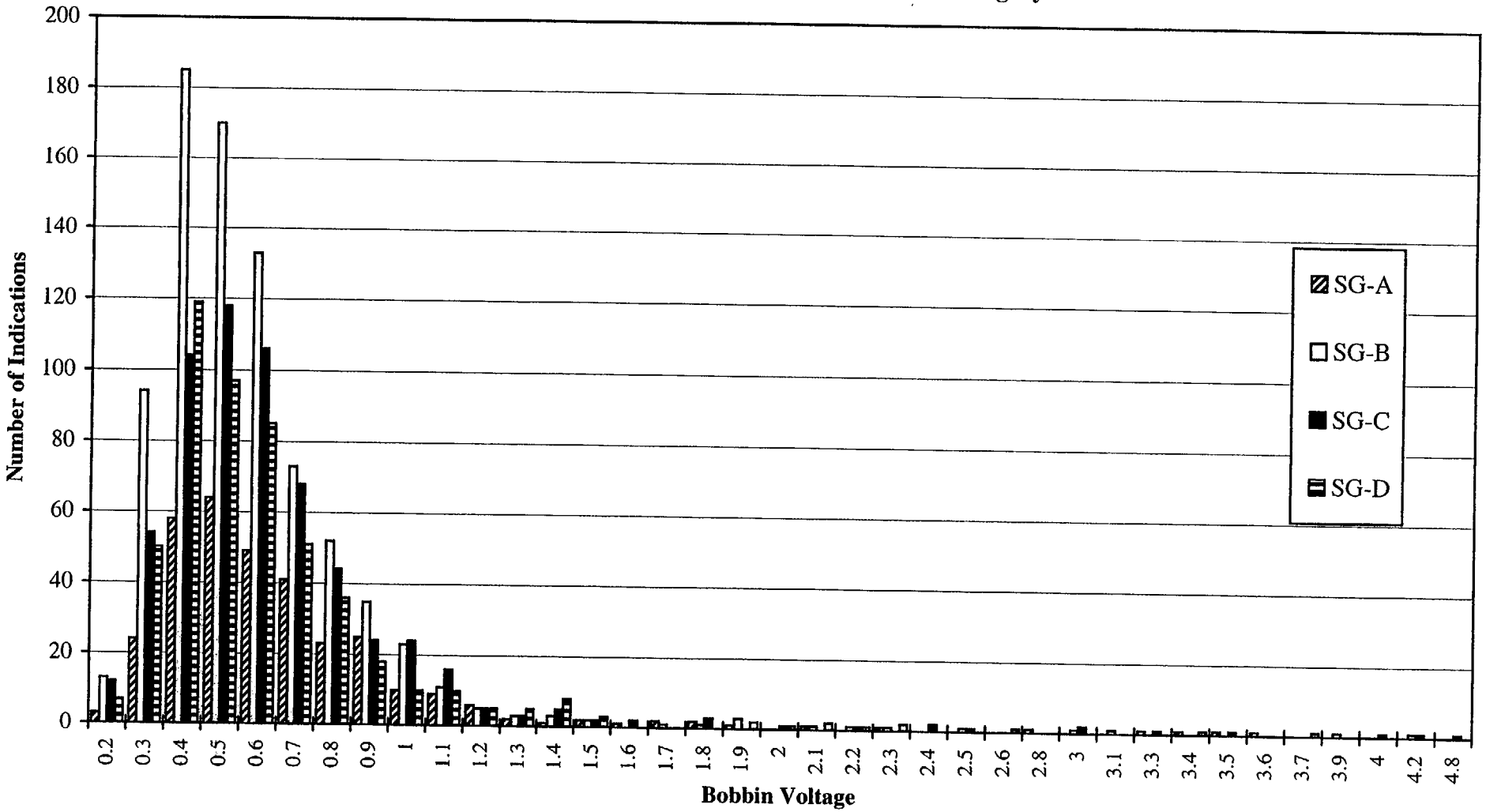
Voltage Bin	New Indications		EOC-6 Bobbin, Field Call in EOC-7 Inspection		EOC-6 Inspection Bobbin	POPCD			
	EOC-7 Inspection RPC Confirmed	EOC-7 Inspection RPC Confirmed plus not Inspected	EOC-7 Inspection RPC Confirmed	EOC-7 Inspection RPC Confirmed plus not Inspected	EOC-6 Inspection Confirmed and Plugged	RPC Confirmed		RPC Confirmed Plus Not Inspected	
						Frac.	Count	Frac.	Count
> 0 - 0.2	2	73	0	120	0	0.0	0 / 2	0.622	120 / 193
0.2 - 0.4	8	472	6	670	0	0.429	6 / 14	0.587	670 / 1142
0.4 - 0.6	15	238	28	401	0	0.651	28 / 43	0.628	401 / 639
0.6 -0 .8	13	65	46	136	0	0.780	46 / 59	0.677	136 / 201
0.8 - 1.0	13	24	32	49	2	0.723	34 / 47	0.680	51 / 75
1.0 - 1.2	5	5	3	3	13	0.762	16 / 21	0.762	16 / 21
1.2 - 1.5	2	2	3	3	10	0.867	13 / 15	0.867	13 / 15
1.5 - 2.0	0	0	0	0	5	1.000	5 / 5	1.000	5 / 5
2.0 - 2.5	0	0	0	0	3	1.000	3 / 3	1.000	3 / 3
2.5 - 3.0	0	0	0	0	2	1.000	2 / 2	1.000	2 / 2
> 3.0	0	0	0	0	1	1.000	1 / 1	1.000	1 / 1
TOTAL	58	879	118	1382	30				
> 1V	0	0	0	0	5				

Table 3-9
South Texas Unit 2
Analysis of RPC Data from EOC-6 and EOC-7 Inspections
Combined Data from All Steam Generators

Group of Indications	Total EOC-6 Inspection Bobbin Indication	Total EOC-7 Inspection Bobbin Indication	Total EOC-7 Inspection RPC Inspected	Total EOC-7 Inspection RPC Confirmed	Percent EOC-7 Inspection RPC Confirmed
Less than or Equal to 1.0 Volt in EOC-7 Inspection					
EOC-6 Inspection Bobbin Left in Service	1327	1269	5	5	100.0
- EOC-6 Inspection RPC Confirmed	0	0	0	0	-
- EOC-6 Inspection RPC NDD	0	0	0	0	-
- EOC-6 Inspection RPC Not Inspected	1269	1269	5	5	100.0
- EOC-6 Indication, NDD in EOC-7 *	58	-	-	-	-
New EOC-7 Inspection Indication	-	833	12	12	100.0
Sum of All EOC-7 Inspection Indication	1327	2102	17	17	100.0
Greater than 1.0 Volt in EOC-7 Inspection					
EOC-6 Inspection Bobbin Left in Service	113	113	113	113	100.0
- EOC-6 Inspection RPC Confirmed	2	2	2	2	100.0
- EOC-6 Inspection RPC NDD	6	6	6	6	100.0
- EOC-6 Inspection RPC Not Inspected	105	105	105	105	100.0
- EOC-6 Indication, NDD in EOC-7 *	0	-	-	-	-
New EOC-7 Inspection Indication	-	47	47	46	97.9
Sum of All EOC-7 Inspection Indication	113	160	160	159	99.4
All Voltages in EOC-7 Inspection					
EOC-6 Inspection Bobbin Left in Service	1440	1382	118	118	100.0
- EOC-6 Inspection RPC Confirmed	2	2	2	2	100.0
- EOC-6 Inspection RPC NDD	6	6	6	6	100.0
- EOC-6 Inspection RPC Not Inspected	1374	1374	110	110	100.0
- EOC-6 Indication, NDD in EOC-7 *	58	-	-	-	-
New EOC-7 Inspection Indication	-	880	59	58	98.3
Sum of All EOC-7 Inspection Indication	1440	2262	177	176	99.4

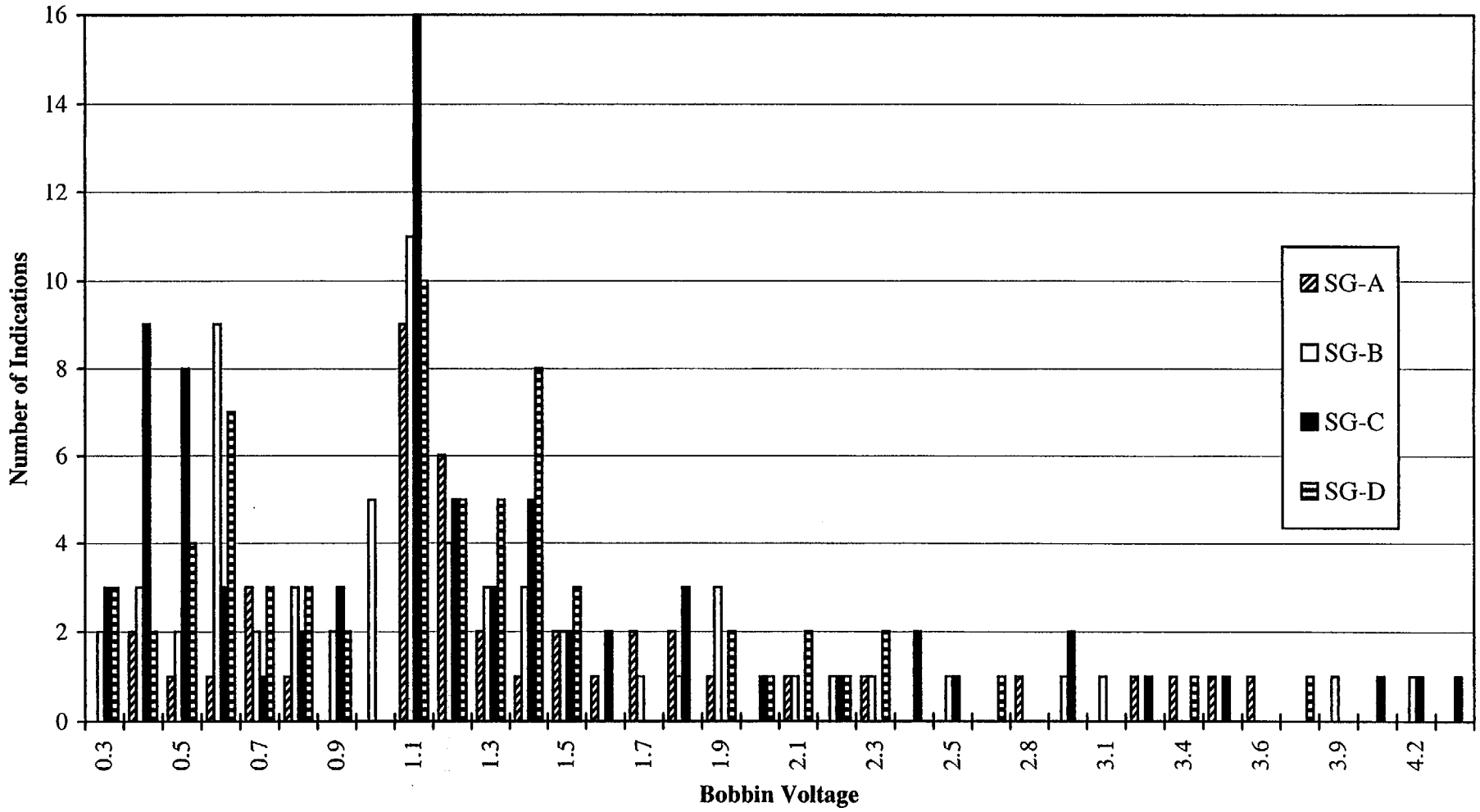
* No indication detected during the EOC-7 inspection. Indications split is based on EOC-6 Inspection bobbin voltage

Figure 3-1
South Texas Unit 2 October 1999 Outage
Bobbin Voltage Distributions at EOC-7 for Tubes in Service During Cycle 7



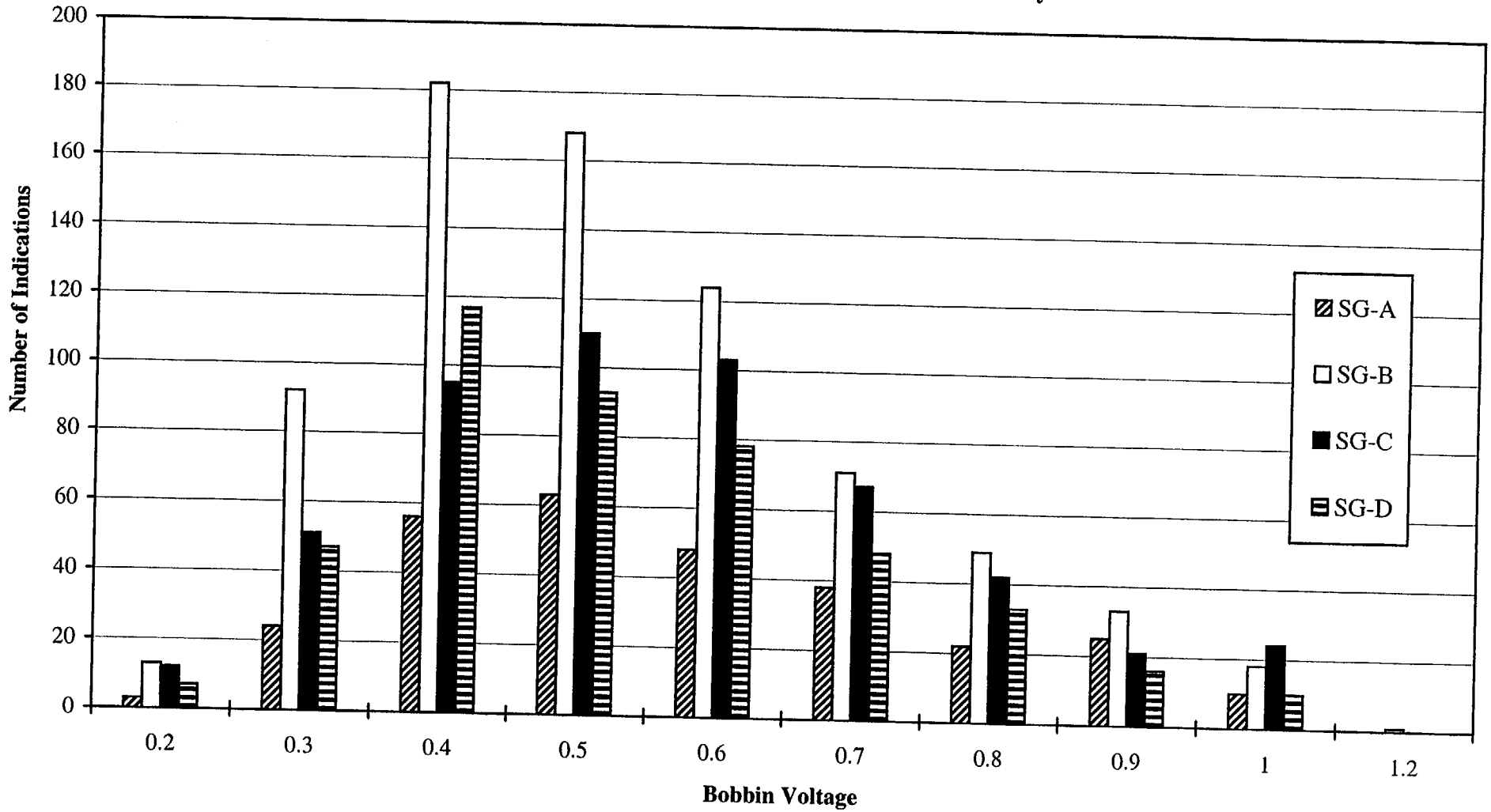
BobnrpcFig1]

Figure 3-2
South Texas Unit 2 October 1999 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 7 Service



BobnrpcFig2

Figure 3-3
South Texas Unit 2 October 1999 Outage
Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 8



BobnrpcFig3

Figure 3-4
South Texas Unit 2 - October 1999
ODSCC Axial Distributions for Tubes in Service During Cycle 7

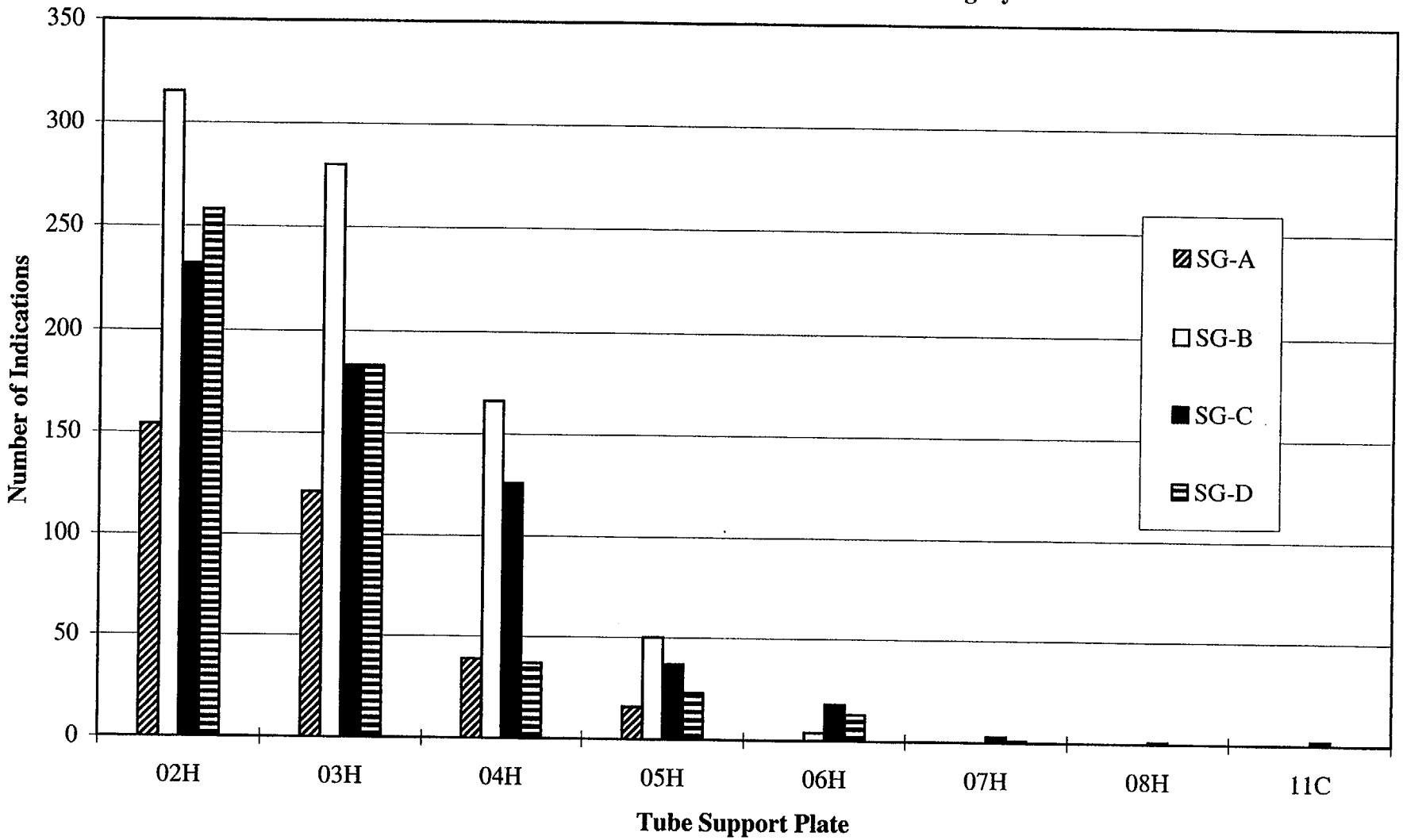


Figure 3-5
South Texas Unit 2 Cycle 7 (October 1998 to October 1999)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

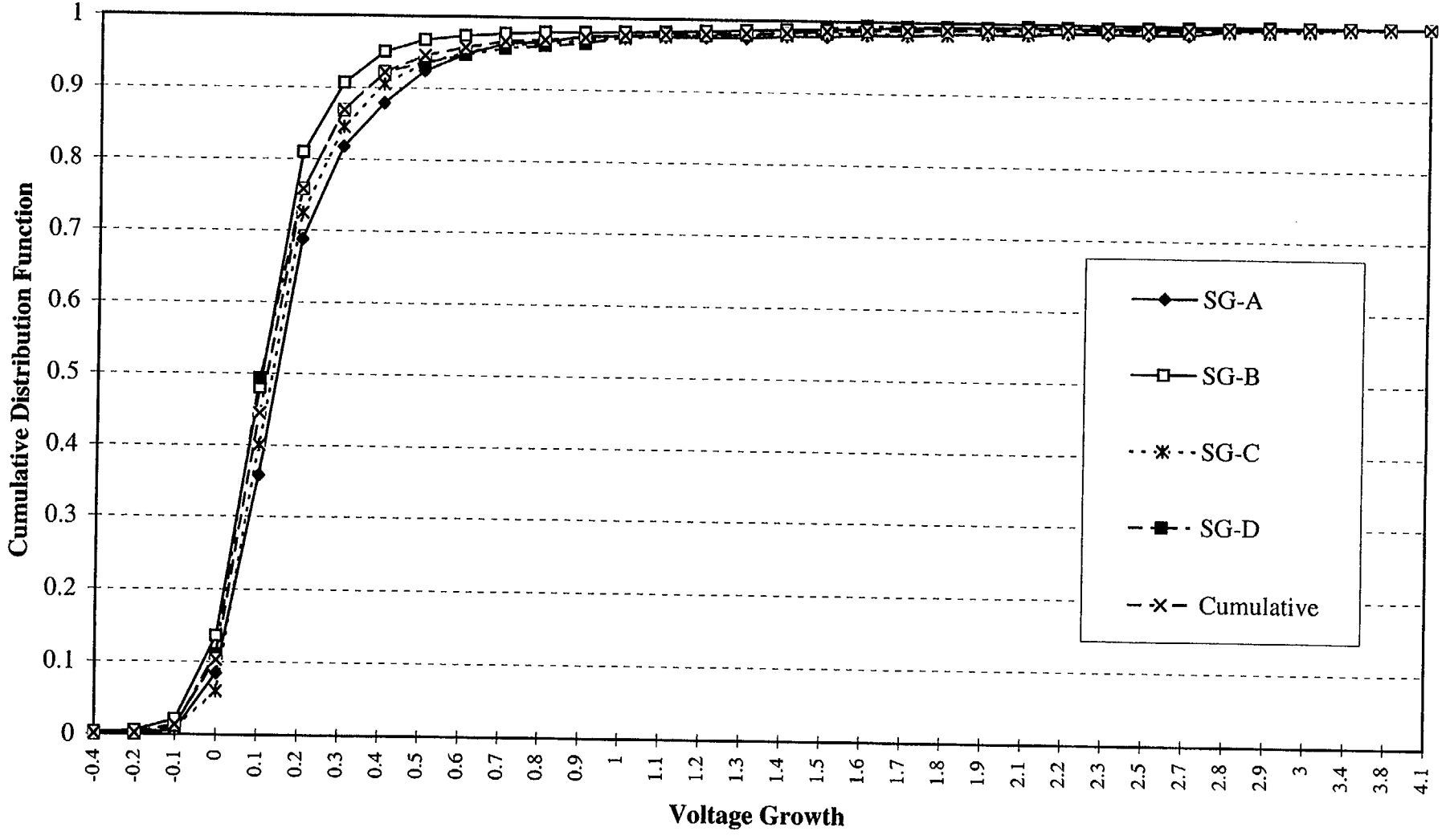


Figure 3-6
South Texas Unit 2 - October 1999
Bobbin Signal Growth History - Cumulative Probability Distributions on an EFPY Basis
Composite of All Steam Generators

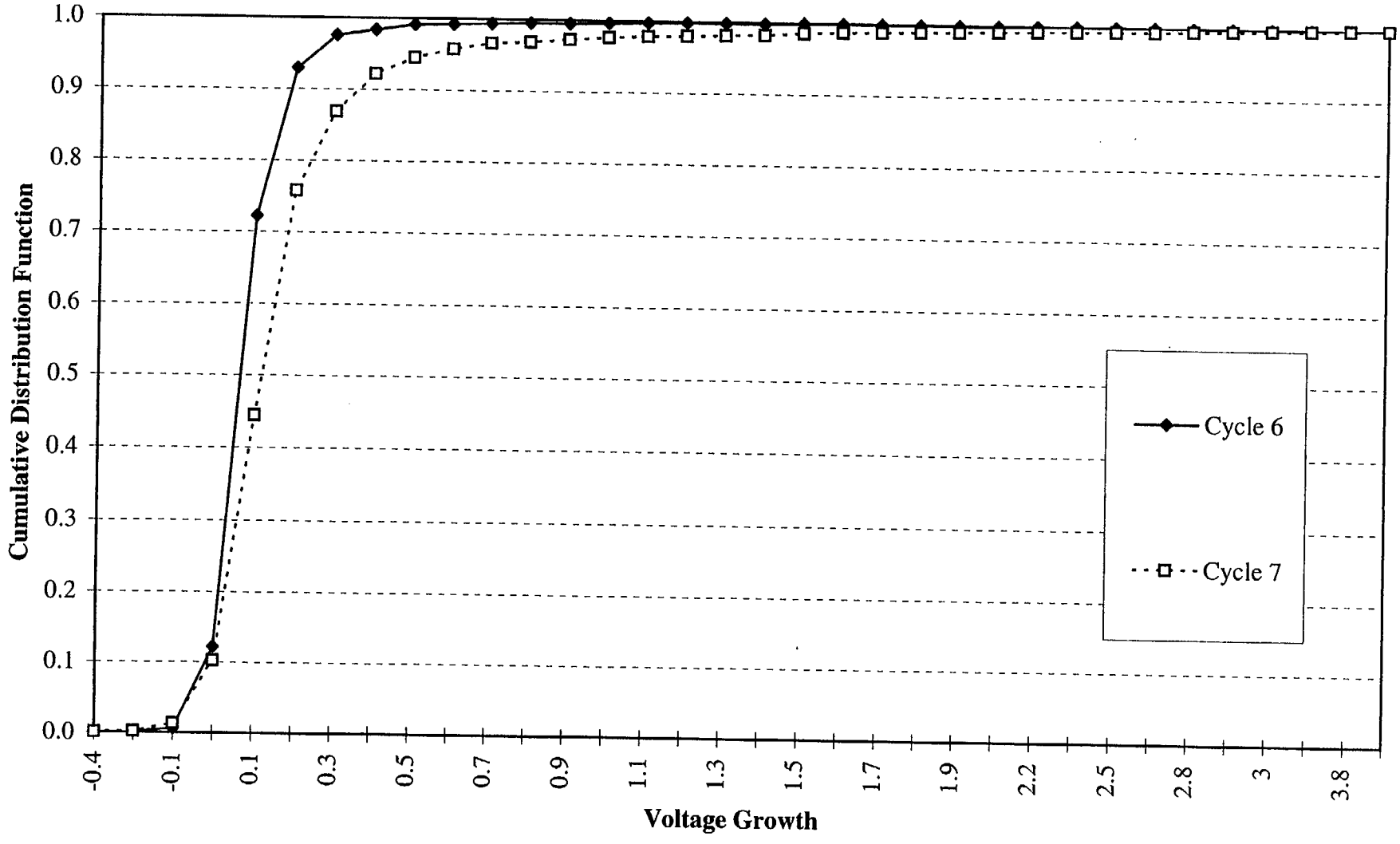


Figure 3-7
South Texas Unit -2 October 1999 Outage
Voltage Growth During Cycle 7 vs BOC-7 Voltage

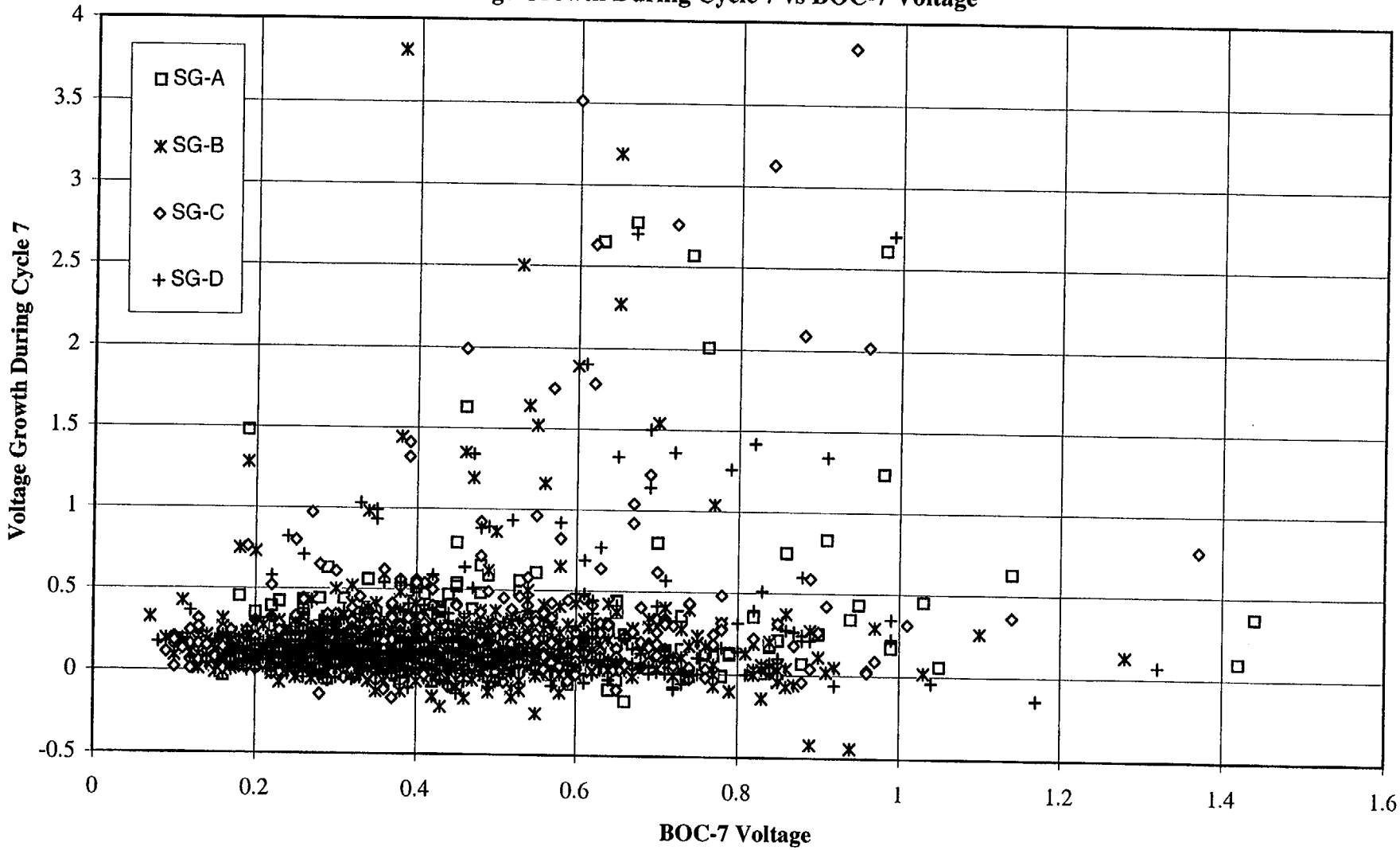


Figure 3-8
NDE Uncertainty Distributions

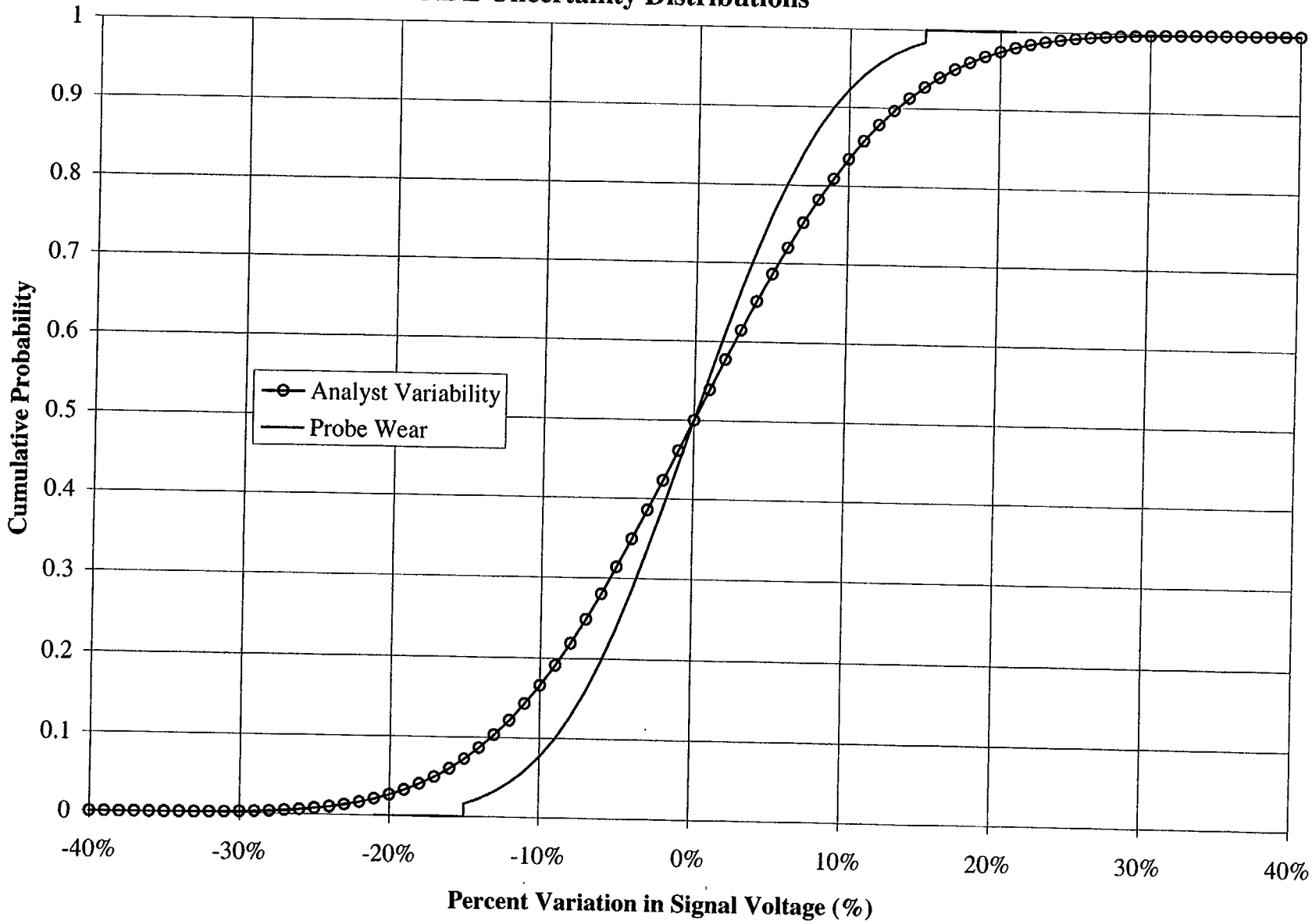
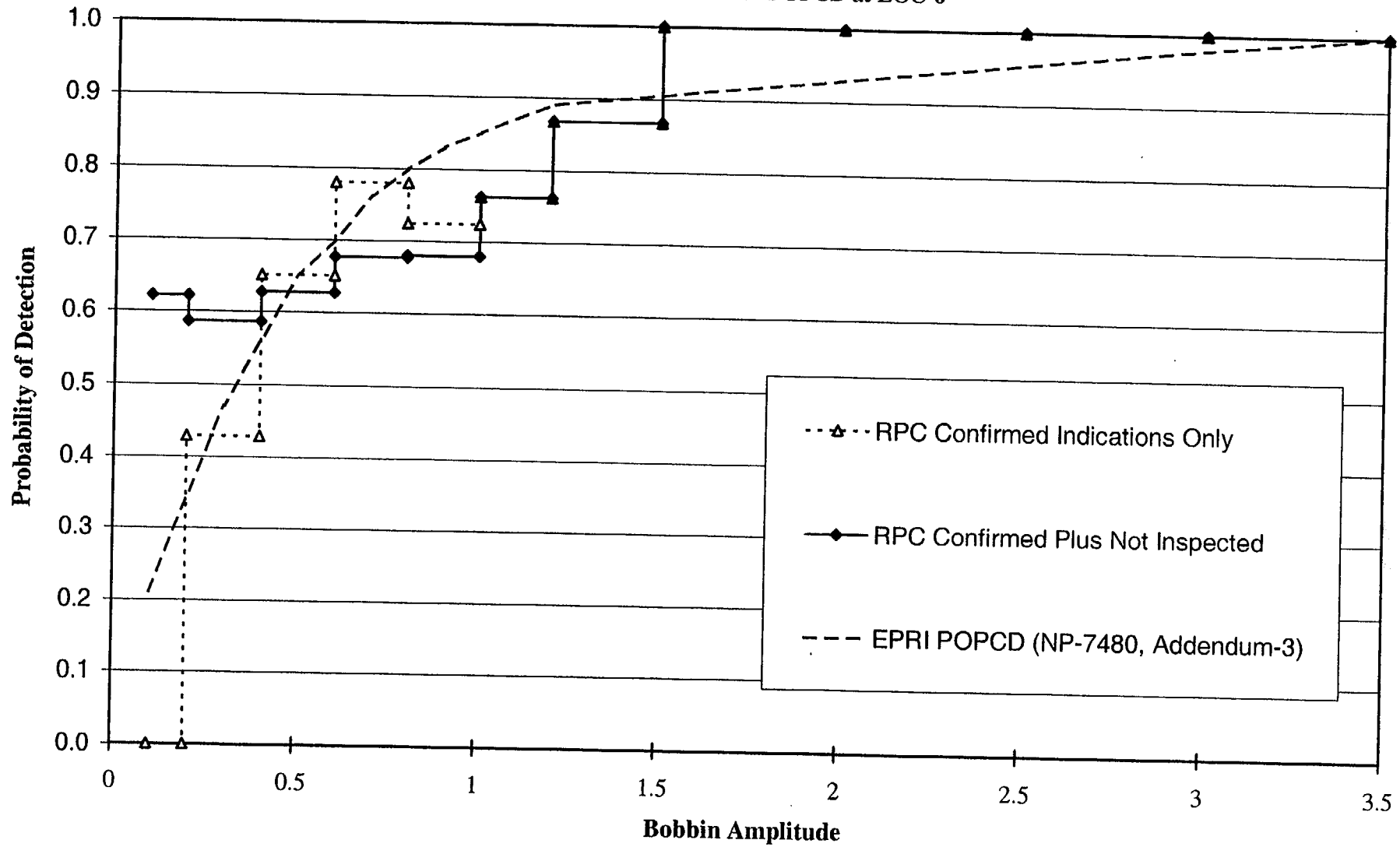


Figure 3-9
South Texas Unit 2
1999 EOC-7 Evaluation for POPCD at EOC-6



Popcd|Fig1|12/7/99|8:50 AM

Figure 3-10
South Texas Unit-2 -- EOC-7 Inspection
Comparison of Worn Probe Voltage Against New Probe Voltage

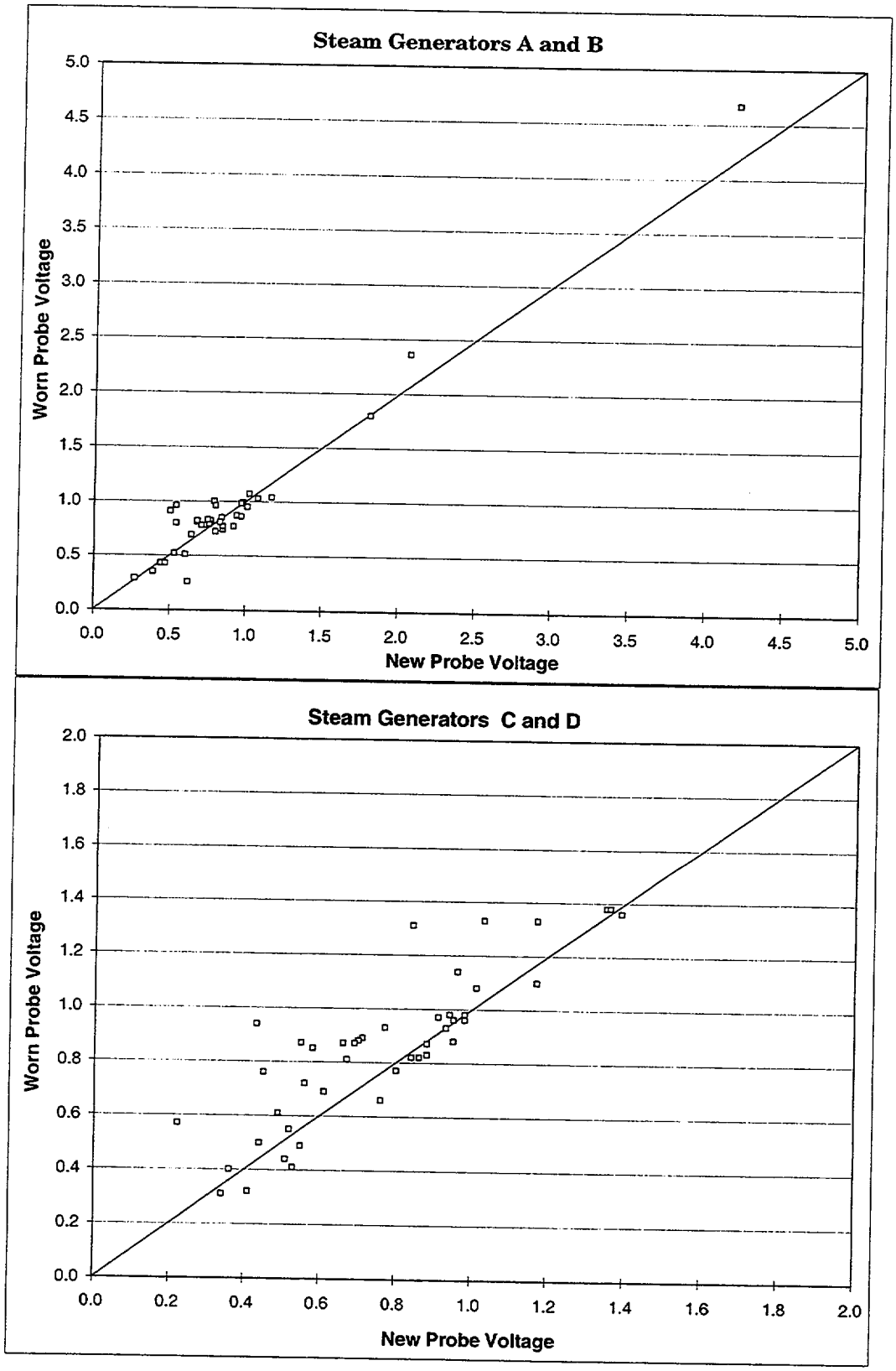
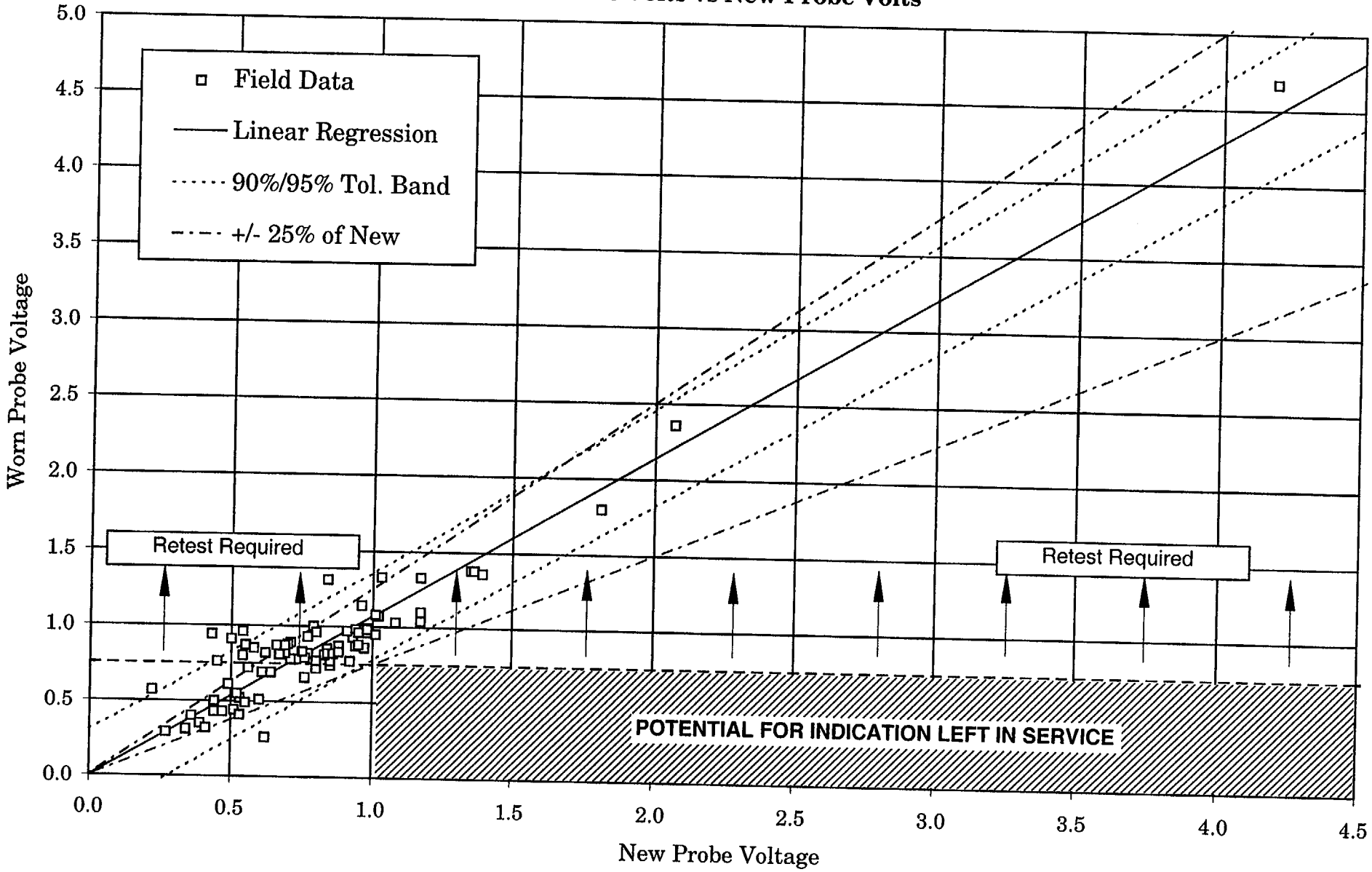


Figure 3-11
South Texas Unit-2 October 1999
Worn Probe Volts vs New Probe Volts



[Probwear] Fig4-12 12/14/99 12:23 PM

4.0 Database Applied for Leak and Burst Correlations

Leak and burst correlations based on the latest available database for ¾" tubes are applied in the analyses presented in this report, and these correlations are documented in Reference 8-5. South Texas pulled tube data from 1998, 1995 and 1993 inspections are included in the database utilized. The database meets the NRC requirement that the p value obtained from the regression analysis of leak rate 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 8-5). The leak rate correlation shown is for SLB differential pressure of 2405 psi.

$$\text{Burst Pressure } (ksi) = 7.40278 - 2.91382 \times \log(volts)$$

$$\text{Probability of Leak} = \frac{1}{1 + e^{\left(4.8082 - 8.4215 \times \log(volts)\right)}}$$

$$\text{Leak Rate } (l/hr) = 10^{\left(-1.8708 + 2.9767 \times \log(volts)\right)}$$

The upper voltage repair limit applied at the EOC-7 inspection, documented in Reference 8-7, was developed using the database presented in Reference 8-4. The structural limit (V_{sl}) for the TSP indications established using 3 times normal operation ΔP value (3675 psid) is 5.80 volts, and V_{sl} for the FDB intersections using 1.43 times the SLB ΔP of 2405 psid is 4.79 volts. The allowance for voltage growth used is 49%/EFPY, which is the highest average growth rate on an individual SG basis for South Texas Unit-2 Cycle 6 operation, which is above the minimum value (30%/EFPY) specified in the Generic Letter 95-05. For the expected 1.27 EFPY (465 EFPD) for Cycle 8, the growth allowance becomes 62%. The allowance for NDE uncertainty is 20% per Generic Letter 95-05. The upper voltage repair limits then become 3.19 volts for TSP indications and 2.63 volts for FDB indications. These values were applied at the EOC-7 inspection to assure that indications exceeding these limits were repaired independent of RPC confirmation.

Based on the actual highest average growth rate for Cycle 7 (52.3%/EFPY) and a

Cycle 8 duration of 461 EFPD, the upper voltage repair limits for TSP and FDB indications become 3.12 volts and 2.58 volts, respectively, which differ by less than 0.1 volt from the limits applied during the EOC-7 inspection.

5.0 SLB Analysis Methods

Monte Carlo analyses are used to calculate the SLB leak rates and tube burst probabilities for both actual EOC-7 and projected EOC-8 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. It is consistent with the methodology applied to obtain the leak rate and tube burst probability results presented in the last 90-day report (Reference 8-2) and the 1-volt repair criteria licensing methodology.

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 and as well as leak and burst results based on those distributions. Equation 3.5 in Reference 8-3 was used to determine the true BOC voltage.

6.0 Bobbin Voltage Distributions

This section describes the salient input data used to calculate EOC bobbin voltage distributions and presents results of calculations to project EOC-8 voltage distributions. Also, EOC-7 voltage projections performed during the last outage based on the EOC-6 inspection bobbin voltage data are compared with the actual bobbin distributions from the current inspection.

6.1 Calculation of Voltage Distributions

The analysis for EOC voltage distribution starts with a cycle initial voltage distribution which is projected to the end of cycle conditions based on the growth rate and the anticipated cycle operating period. The number of indications assumed in the analysis to project EOC voltage distributions, and to perform tube leak rate and burst probability analyses, is obtained by adjusting the number of reported indications to account for detection uncertainty and birth of new indications over the projection period. This is accomplished by using a POD factor, which is defined as the ratio of the actual number of indications detected to total number of indications present. A conservative value is assigned to POD based on historic data, and the value used herein is discussed in Section 6-2. The calculation of projected bobbin voltage frequency distribution is based on a net total number of indications returned to service, defined as follows.

$$N_{Tot\ RTS} = N_i / POD - N_{repaired} + N_{deplugged}$$

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) identified after the previous cycle,
POD	=	Probability of detection,
$N_{repaired}$	=	Number of N_i which are repaired (plugged) after the last cycle,
$N_{deplugged}$	=	Number of indications in tubes deplugged after the last cycle and returned to service in accordance with voltage-based repair criteria.

There are no deplugged tubes returned to service at BOC-8; therefore, $N_{deplugged} = 0$.

The methodology used in the projection of bobbin voltage frequency predictions is

described in Reference 8-3. Salient input data used for projecting EOC-8 bobbin voltage frequency are further discussed below.

6.2 Probability of Detection (POD)

The Generic Letter 95-05 (Reference 8-1) requires the application of a constant POD value of 0.6 to define the BOC distribution for EOC voltage projections, unless an alternate POD is approved by the NRC. A POD value of 1.0 represents the ideal situation where all indications are detected. A voltage-dependent POD would yield a more accurate prediction of voltage distributions consistent with voltage-based repair criteria experience. In this report both NRC mandated constant POD of 0.6 as well as a voltage-dependent POD developed for EPRI (POPCD) are used. The EPRI POPCD distribution developed by analysis of data for 19 inspections in 10 plants and presented in Table 7-4 of Reference 8-4 was applied. The POPCD values applied represent a lower 95% confidence bound, and their distribution is graphically illustrated in Figure 6-1.

6.3 Limiting Growth Rate Distribution

As discussed in Section 3.2, the NRC guidelines in Generic Letter 95-05 stipulate that the more conservative growth rate distribution from the past two inspections should be utilized for projecting EOC distributions for the next cycle. It is evident from Table 3-5 that the average growth rate during Cycle 7 is significantly higher than in Cycle 6. Also, the data in Figure 3-6 show that Cycle 7 growth distribution is more limiting than the Cycle 6 growth distribution. Hence, SLB leak rate and tube burst probability projection for the EOC-8 conditions should be based on the Cycle 7 data.

As noted in Section 3.2, Cycle 7 growth rates for SGs A and C are higher than the composite growth distribution and, per the methodology recommended in Reference 8-3, SG-specific growth rates are to be used for SGs A and C while the composite growth rates should be applied for SGs B and D. The growth data for SG-A does not include any of the top 5 growths observed for Cycle 7; therefore, leak and burst projection for SG-A was performed using both its own growth distribution as well as the composite growth and the limiting result is presented. Composite growth rates were applied for the other two SGs (SGs B and D).

A number of indications had a relatively large voltage growth (in excess of 2 volts) during Cycle 7. Although this growth behavior is likely to be a one time event,

additional sensitivity analyses were performed to examine the impact of the this growth trend continuing in Cycle 8. EOC-8 leak rates and burst probabilities for all SGs were also estimated using conservative growth distributions obtained by combining SG-specific Cycle 7 growth data with the top 3 growth values for Cycle 7 (if they are not already part of the SG-specific growth data). Results of this sensitivity analysis are presented in Table 7-3.

The Cycle 7 growth data shows a dependency on the BOC-7 voltage (see Figure 3-7). Hence, leak and burst analyses for SGs A and C (SGs with a more limiting growth distribution than the remaining 2 SGs) were also repeated taking into account the growth dependency on the BOC voltage in accordance with the methodology recommended in Reference 8-4 for considering growth dependency on BOC voltage. These results are also included in Table 7-3.

6.4 Cycle Operating Period

The operating periods used in the growth rate/EFPY calculations and voltage projections are as follows.

Cycle 7 - BOC-7 to EOC-7 - 342.5 EFPD or 0.94 EFPY (actual)
Cycle 8 - BOC-8 to EOC-8 - 461 EFPD or 1.26 EFPY (estimated)

6.5 Projected EOC-8 Voltage Distribution

Calculations for EOC-8 bobbin voltage projections were performed for all four SGs based on the EOC-7 distributions shown in Table 6-2. The BOC distributions were adjusted to account for probability of detection as described above, and the adjusted number of indications at BOC-8 are also shown in Table 6-2. Calculations for all SGs were performed using a constant POD of 0.6. For the limiting SG, SG-C, EOC-8 projections were also performed using the voltage-dependent EPRI POPCD distribution (presented in Table 6-1). As stated in Section 6-2, EOC-7 growth rates shown in Table 3-3, were applied. The EOC-8 voltage distributions thus projected for all four SGs are summarized on Table 6-3 and illustrated in Figures 6-2 through 6-4. The results based on POD=0.6 are more conservative than those using the voltage-dependent EPRI POPCD (available only for the limiting SG, SG-C).

6.6 Comparison of Actual and Projected EOC-7 Voltage Distributions

Table 6-4, and Figures 6-5 and 6-6 provide a comparison of the EOC-7 actual measured bobbin voltage distributions with the corresponding projections

performed using the last (EOC-6) inspection bobbin voltage data which is presented in Reference 8-2. A comparison of the actual and projected voltage distributions in Figures 6-5 and 6-6 show that in general the indication population above about 1.5 volts is underestimated in the projections based on both a constant POD of 0.6 and POPCD for all SGs. Also, for indications below about 0.5 volts, indication population based on POD=0.6 underestimate the actual population. This POD value is conservative for voltages above about 0.5 volts but non-conservative below 0.5 volts as seen in Figure 6-1.

Table 6-1
EPRI POPCD Distribution
Based on Data from 19 Inspections in 10 Plants

Voltage Bin	EPRI POPCD#
0.1	0.26
0.2	0.36
0.3	0.46
0.4	0.54
0.5	0.63
0.6	0.68
0.7	0.74
0.8	0.78
0.9	0.81
1	0.84
1.2	0.87
1.4	0.90
1.6	0.91
1.8	0.92
2	0.93
3	0.98
3.5	1.0

Data from Table 7-4 in Reference 8-4.

Table 6-2 (Sheet 1 of 2)
South Texas Unit 2 October 1999
EOC-7 Bobbin and Assumed BOC-8 Bobbin Distributions in SLB Leak Rate and Tube Burst Analyses

Voltage Bin	Steam Generator A				Steam Generator B			
	EOC - 7		BOC - 8		EOC - 7		BOC - 8	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.2	3	0	5.00	8.33	13	0	21.67	36.11
0.3	24	0	40.00	52.17	94	2	154.67	202.35
0.4	58	2	94.67	105.41	185	3	305.33	339.59
0.5	64	1	105.67	100.59	170	2	281.33	267.84
0.6	49	1	80.67	70.01	133	9	212.67	183.75
0.7	41	3	65.33	51.67	73	2	119.67	95.33
0.8	23	1	37.33	28.11	52	3	83.67	62.82
0.9	25	0	41.67	30.49	35	2	56.33	40.68
1	10	0	16.67	11.90	23	5	33.33	22.38
1.1	9	9	6.00	1.53	11	11	7.33	1.87
1.2	6	6	4.00	0.90	5	4	4.33	1.75
1.3	2	2	1.33	0.27	3	3	2.00	0.41
1.4	1	1	0.67	0.12	3	3	2.00	0.37
1.5	2	2	1.33	0.22	2	2	1.33	0.22
1.6	1	1	0.67	0.10	0	0	0.00	0.00
1.7	2	2	1.33	0.19	1	1	0.67	0.09
1.8	2	2	1.33	0.17	1	1	0.67	0.09
1.9	1	1	0.67	0.08	3	3	2.00	0.24
2	0	0	0.00	0.00	0	0	0.00	0.00
2.1	1	1	0.67	0.07	1	1	0.67	0.07
2.2	0	0	0.00	0.00	1	1	0.67	0.06
2.3	1	1	0.67	0.06	1	1	0.67	0.06
2.4	0	0	0.00	0.00	0	0	0.00	0.00
2.5	0	0	0.00	0.00	1	1	0.67	0.05
2.6	0	0	0.00	0.00	0	0	0.00	0.00
2.8	1	1	0.67	0.03	0	0	0.00	0.00
3	0	0	0.00	0.00	1	1	0.67	0.02
3.1	0	0	0.00	0.00	1	1	0.67	0.02
3.3	1	1	0.67	0.01	0	0	0.00	0.00
3.4	1	1	0.67	0.00	0	0	0.00	0.00
3.5	1	1	0.67	0.00	0	0	0.00	0.00
3.6	1	1	0.67	0.00	0	0	0.00	0.00
3.7	0	0	0.00	0.00	0	0	0.00	0.00
3.9	0	0	0.00	0.00	1	1	0.67	0.00
4	0	0	0.00	0.00	0	0	0.00	0.00
4.2	0	0	0.00	0.00	1	1	0.67	0.00
4.8	0	0	0.00	0.00	0	0	0.00	0.00
Total	330	41	509.00	462.44	815	64	1294.33	1256.18
> 1V	33	33	22.00	3.75	37	36	25.67	5.31
> 2V	7	7	4.67	0.17	8	8	5.33	0.28

Table 6-2 (Sheet 2 of 2)
South Texas Unit 2 October 1999
EOC-7 Bobbin and Assumed BOC-8 Bobbin Distributions in SLB Leak Rate and Tube Burst Analyses

Voltage Bin	Steam Generator C				Steam Generator D			
	EOC - 7		BOC - 8		EOC - 7		BOC - 8	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.2	12	0	20.00	33.33	7	0	11.67	19.44
0.3	54	3	87.00	114.39	50	3	80.33	105.70
0.4	104	9	164.33	183.59	119	2	196.33	218.37
0.5	118	8	188.67	179.30	97	4	157.67	149.97
0.6	106	3	173.67	150.62	85	7	134.67	116.19
0.7	68	1	112.33	89.67	51	3	82.00	65.00
0.8	44	2	71.33	53.70	36	3	57.00	42.57
0.9	24	3	37.00	26.27	18	2	28.00	19.95
1	24	0	40.00	28.57	10	0	16.67	11.90
1.1	16	16	10.67	2.71	10	10	6.67	1.70
1.2	5	5	3.33	0.75	5	5	3.33	0.75
1.3	3	3	2.00	0.41	5	5	3.33	0.68
1.4	5	5	3.33	0.62	8	8	5.33	0.99
1.5	2	2	1.33	0.22	3	3	2.00	0.33
1.6	2	2	1.33	0.20	0	0	0.00	0.00
1.7	0	0	0.00	0.00	0	0	0.00	0.00
1.8	3	3	2.00	0.26	0	0	0.00	0.00
1.9	0	0	0.00	0.00	2	2	1.33	0.16
2	1	1	0.67	0.08	1	1	0.67	0.08
2.1	0	0	0.00	0.00	2	2	1.33	0.14
2.2	1	1	0.67	0.06	1	1	0.67	0.06
2.3	0	0	0.00	0.00	2	2	1.33	0.12
2.4	2	2	1.33	0.11	0	0	0.00	0.00
2.5	1	1	0.67	0.05	0	0	0.00	0.00
2.6	0	0	0.00	0.00	1	1	0.67	0.04
2.8	0	0	0.00	0.00	0	0	0.00	0.00
3	2	2	1.33	0.04	0	0	0.00	0.00
3.1	0	0	0.00	0.00	0	0	0.00	0.00
3.3	1	1	0.67	0.01	0	0	0.00	0.00
3.4	0	0	0.00	0.00	1	1	0.67	0.00
3.5	1	1	0.67	0.00	0	0	0.00	0.00
3.6	0	0	0.00	0.00	0	0	0.00	0.00
3.7	0	0	0.00	0.00	1	1	0.67	0.00
3.9	0	0	0.00	0.00	0	0	0.00	0.00
4	1	1	0.67	0.00	0	0	0.00	0.00
4.2	1	1	0.67	0.00	0	0	0.00	0.00
4.8	1	1	0.67	0.00	0	0	0.00	0.00
Total	602	77	926.33	864.95	515	66	792.33	754.14
> 1V	48	48	32.00	5.51	42	42	28.00	5.05
> 2V	11	11	7.33	0.27	8	8	5.33	0.36

Table 6-3
South Texas Unit 2 October 1999
Voltage Distribution Projection for EOC - 8

Voltage Bin	Steam Generator A	Steam Generator B	Steam Generator C		Steam Generator D
	Projected Number of Indications at EOC - 8				
	POD 0.6	POD 0.6	POD 0.6	POPCD	POD 0.6
0.1	0.03	0.11	0.06	0.10	0.06
0.2	0.84	3.44	1.54	2.42	1.82
0.3	5.96	22.78	10.83	17.08	12.50
0.4	21.03	74.37	37.28	53.09	42.08
0.5	44.07	143.22	77.45	97.54	84.82
0.6	64.42	193.20	115.63	124.84	115.31
0.7	72.66	201.45	134.91	131.19	121.97
0.8	68.49	174.73	129.75	112.38	107.57
0.9	58.23	136.38	108.77	81.36	85.42
1.0	46.49	100.39	83.76	55.23	62.58
1.1	35.06	71.02	61.56	41.54	43.49
1.2	24.84	48.18	43.67	35.95	29.25
1.3	16.57	31.27	29.69	28.08	19.40
1.4	10.69	19.81	19.58	18.18	12.91
1.5	6.95	12.84	13.01	11.44	9.01
1.6	4.78	8.80	9.01	7.59	6.58
1.7	3.52	6.40	6.62	5.73	4.92
1.8	2.74	4.78	5.05	4.08	3.66
1.9	2.18	3.67	3.92	2.68	2.78
2.0	1.79	3.02	3.05	1.83	2.26
2.1	1.52	2.68	2.42	1.52	2.00
2.2	1.37	2.65	2.04	1.58	1.96
2.3	1.28	2.67	1.79	2.20	2.00
2.4	1.16	2.51	1.53	2.17	1.88
2.5	1.01	2.18	1.23	1.28	1.67
2.6	0.86	1.85	1.03	0.57	1.42
2.7	0.75	1.59	1.02	0.28	1.19
2.8	0.64	1.32	1.09	0.60	0.97
2.9	0.55	1.08	1.07	0.76	0.76
3.0	0.50	1.00	1.04	0.70	0.67
3.1	0.52	1.04	1.12	1.15	0.66
3.2	0.55	1.04	1.27	1.32	0.66
3.3	0.53	0.90	1.31	1.06	0.57
3.4	0.49	0.72	1.18	1.18	0.47
3.5	0.46	0.59	0.94	1.36	0.41
3.6	0.42	0.50	0.70	1.08	0.35
3.7	0.39	0.46	0.55	0.69	0.32
3.8	0.39	0.57	0.52	0.39	0.38
3.9	0.42	0.77	0.56	0.19	0.50
4.0	0.47	0.97	0.62	0.09	0.61
4.1	0.49	1.05	0.68	0.18	0.66
4.2	0.45	0.95	0.69	0.59	0.60
4.3	0.37	0.73	0.63	0.88	0.46
4.4	0.28	0.52	0.52	1.08	0.33
4.5	0.21	0.40	0.45	0.89	0.24
4.6	0.19	0.40	0.46	0.56	0.23
4.7	0.18	0.42	0.49	0.33	0.24
4.8	0.15	0.35	0.48	0.37	0.20
4.9	0.09	0.25	0.40	0.68	0.15
5.0	0.00	0.19	0.34	0.64	0.11
5.1	0.00	0.19	0.38	0.43	0.11
5.2	0.00	0.21	0.43	0.27	0.12
5.3	0.00	0.18	0.43	0.33	0.04
5.4	0.70	0.18	0.42	0.66	0.00
5.5	0.00	0.26	0.44	0.78	0.00
5.6	0.00	0.11	0.45	1.08	0.70
5.7	0.00	0.00	0.42	0.92	0.00
5.8	0.30	0.70	0.06	0.77	0.00
5.9	0.00	0.00	0.00	0.77	0.30
6.0	0.00	0.30	0.70	0.32	0.00
6.2	0.00	0.00	0.30	0.70	0.00
6.3	0.00	0.00	0.00	0.30	0.00
TOTAL	509.03	1294.34	927.34	866.03	792.33
> 1 V	126.81	244.27	227.36	190.80	158.20
> 2 V	17.69	34.48	32.20	33.70	23.94
> 3 V	8.05	14.95	17.94	22.04	9.42

Table 6-4
South Texas Unit 2 October 1999
Comparison of Predicted and Actual EOC-7 Voltage Distributions

Voltage Bin	Steam Generator A			Steam Generator B			Steam Generator C			Steam Generator D		
	Number of Indications											
	EOC-7 Prediction		EOC-7 Actual	EOC-7 Prediction		EOC-7 Actual	EOC-7 Prediction		EOC-7 Actual	EOC-7 Prediction		EOC-7 Actual
	POD = 0.6	POPCD		POD = 0.6	POPCD		POD = 0.6	POPCD		POD = 0.6	POPCD	
0.1	0.11	0.18	0	1.55	3.20	0	1.15	2.41	0	0.21	0.44	0
0.2	3.70	5.55	3	18.90	33.62	13	13.20	23.72	12	4.08	7.57	7
0.3	22.10	29.83	24	85.52	131.48	94	59.61	90.75	54	28.96	45.17	50
0.4	48.76	60.25	58	159.76	210.61	185	123.77	161.21	104	80.14	107.40	119
0.5	55.20	61.48	64	174.92	204.68	170	151.63	174.63	118	104.14	125.41	97
0.6	46.41	46.69	49	140.98	147.69	133	135.67	140.10	106	99.48	107.72	85
0.7	32.64	30.27	41	103.38	98.09	73	100.54	94.93	68	77.26	76.40	51
0.8	21.99	19.04	23	66.45	58.96	52	64.16	56.62	44	55.61	50.89	36
0.9	15.53	12.66	25	37.90	32.04	35	38.98	32.46	24	38.18	32.73	18
1.0	11.39	8.67	10	20.44	16.62	23	23.57	18.74	24	25.31	20.69	10
1.1	8.15	5.72	9	10.80	8.53	11	13.82	10.59	16	15.92	12.57	10
1.2	5.51	3.52	6	5.60	4.32	5	7.78	5.67	5	9.35	7.15	5
1.3	3.72	2.17	2	3.00	2.33	3	4.41	3.03	3	5.29	3.96	5
1.4	2.94	1.84	1	1.85	1.52	3	2.73	1.80	5	3.10	2.24	8
1.5	2.61	1.80	2	1.25	1.07	2	1.86	1.19	2	2.10	1.48	3
1.6	2.08	1.39	1	0.82	0.70	0	1.31	0.79	2	1.60	1.08	0
1.7	1.54	0.95	2	0.53	0.45	1	0.93	0.52	0	1.18	0.75	0
1.8	1.19	0.76	2	0.38	0.36	1	0.71	0.38	3	0.98	0.71	0
1.9	1.07	0.77	1	0.30	0.29	3	0.60	0.31	0	0.87	0.71	2
2.0	0.84	0.57	0	0.03	0.05	0	0.51	0.20	1	0.64	0.50	1
2.1	0.62	0.38	1	0.00	0.00	1	0.43	0.00	0	0.45	0.32	2
2.2	0.44	0.22	0	0.00	0.00	1	0.36	0.00	1	0.31	0.18	1
2.3	0.34	0.13	1	0.70	0.00	1	0.29	0.00	0	0.23	0.11	2
2.4	0.30	0.09	0	0.00	0.70	0	0.24	0.70	2	0.19	0.09	0
2.5	0.35	0.15	0	0.00	0.00	1	0.08	0.00	1	0.26	0.24	0
2.6	0.59	0.44	0	0.00	0.00	0	0.00	0.00	0	0.46	0.49	1
2.7	0.60	0.22	0	0.00	0.00	0	0.70	0.00	0	0.37	0.11	0
2.8	0.52	0.00	1	0.30	0.30	0	0.00	0.30	0	0.00	0.70	0
2.9	0.38	0.70	0	0.00	0.00	0	0.30	0.00	0	0.70	0.00	0
3.0	0.28	0.00	0	0.00	0.00	1	0.00	0.00	2	0.00	0.30	0
3.1	0.21	0.30	0	0.00	0.00	1	0.00	0.00	0	0.30	0.00	0
3.2	0.16	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
3.3	0.05	0.00	1	0.00	0.00	0	0.00	0.00	1	0.00	0.00	0
3.4	0.00	0.00	1	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1
3.5	0.00	0.00	1	0.00	0.00	0	0.00	0.00	1	0.00	0.00	0
3.6	0.00	0.00	1	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
3.7	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1
3.8	0.70	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
3.9	0.00	0.00	0	0.00	0.00	1	0.00	0.00	0	0.00	0.00	0
4.0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.00	0.00	0
4.2	0.00	0.00	0	0.00	0.00	1	0.00	0.00	1	0.00	0.00	0
4.5	0.30	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
4.8	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.00	0.00	0
6.0	0.00	0.00	0	0.30	0.30	0			0			0
TOTAL	293.32	296.74	330.00	835.66	957.91	815.00	749.34	821.05	602.00	557.67	608.11	515.00
> 1 V	35.49	22.12	33.00	25.86	20.92	37.00	37.06	25.48	48.00	44.30	33.69	42.00
> 2 V	5.84	2.63	7.00	1.30	1.30	8.00	2.40	1.00	11.00	3.27	2.54	8.00

Figure 6-1
Generic POPCD Distribution Based on 19 Inspections in 10 Plants
[Presented in EPRI Report NP-7480, Addendum-2]

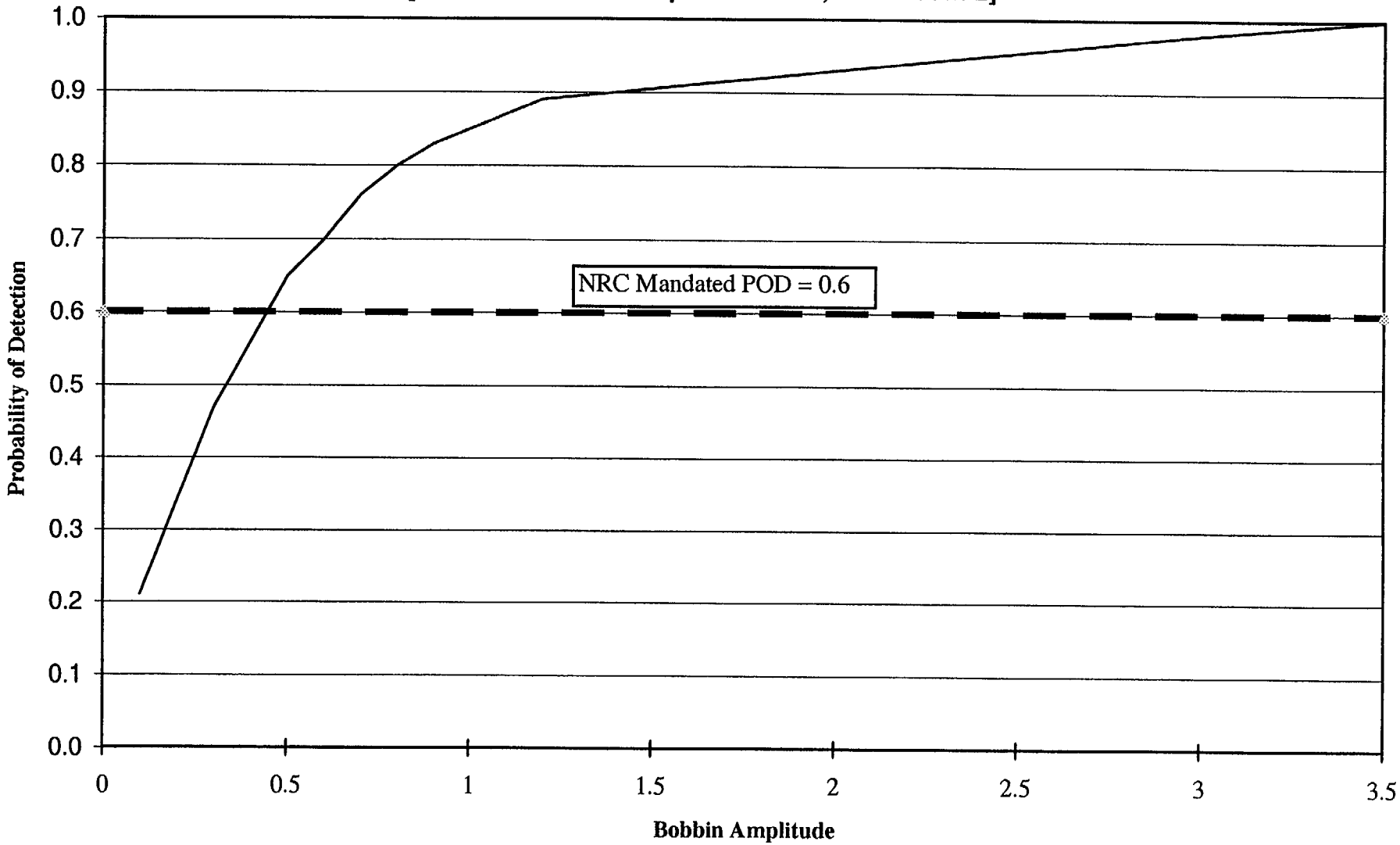
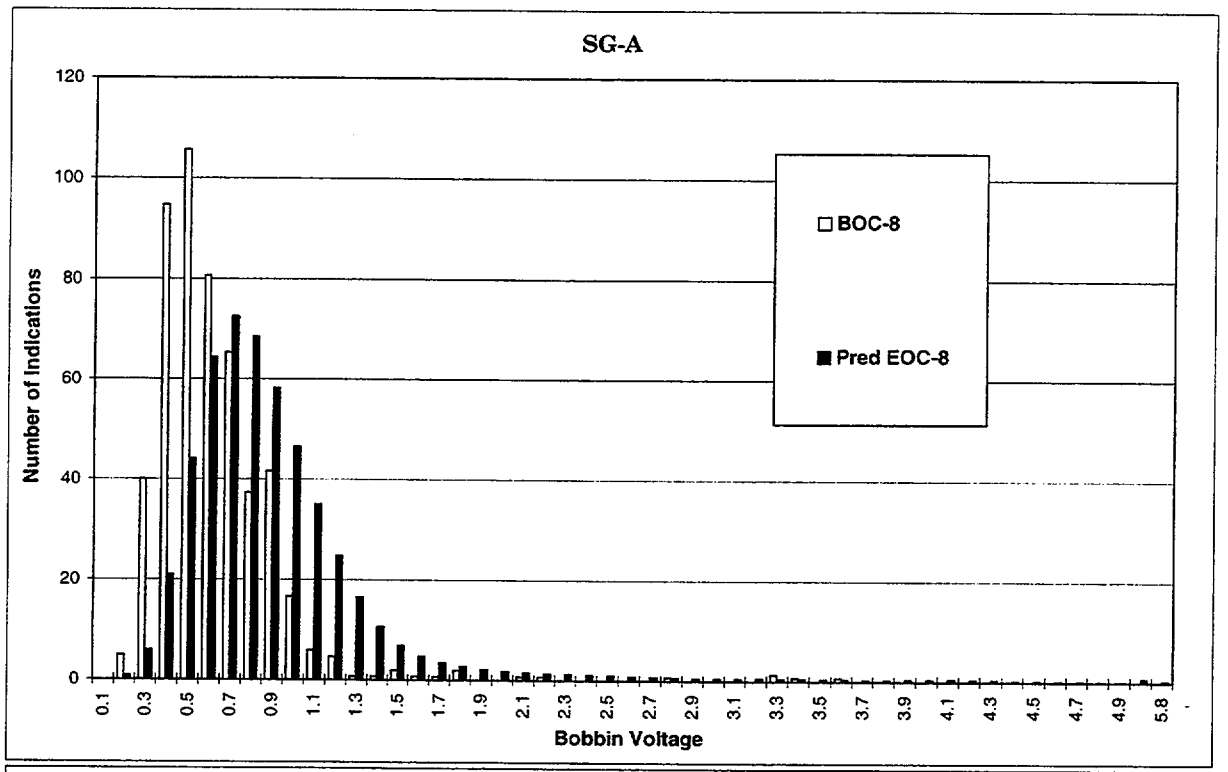


Figure 6-2
South Texas Unit 2 -- SGs A and B
Predicted Bobbin Voltage Distribution for Cycle 8 - POD = 0.6



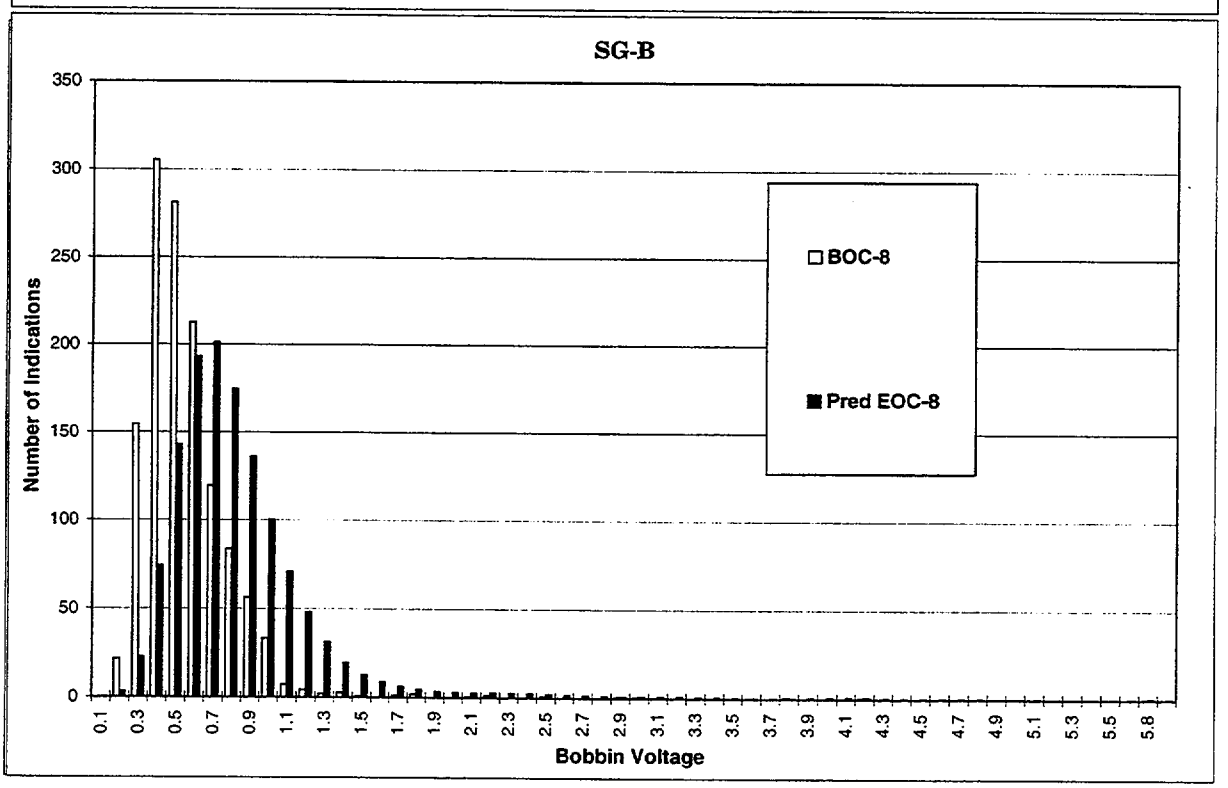
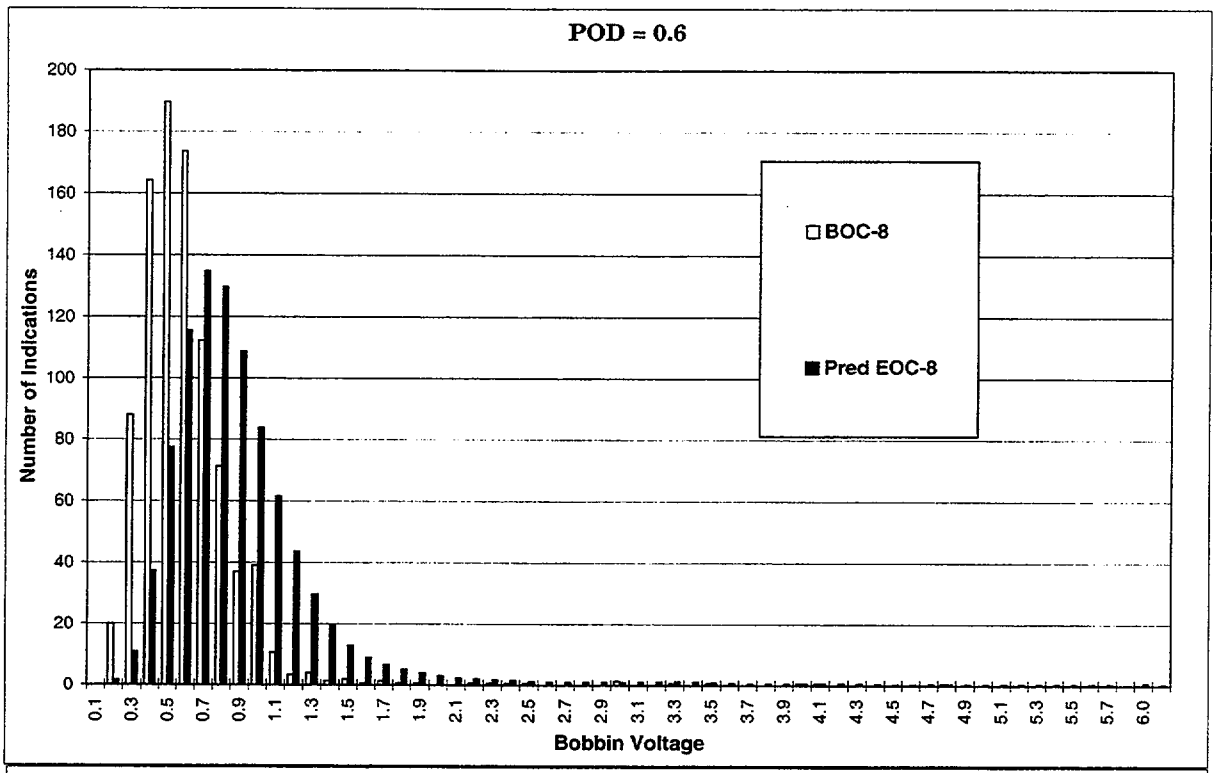


Figure 6-3
South Texas Unit 2 SG-C
Predicted Bobbin Voltage Distribution for Cycle



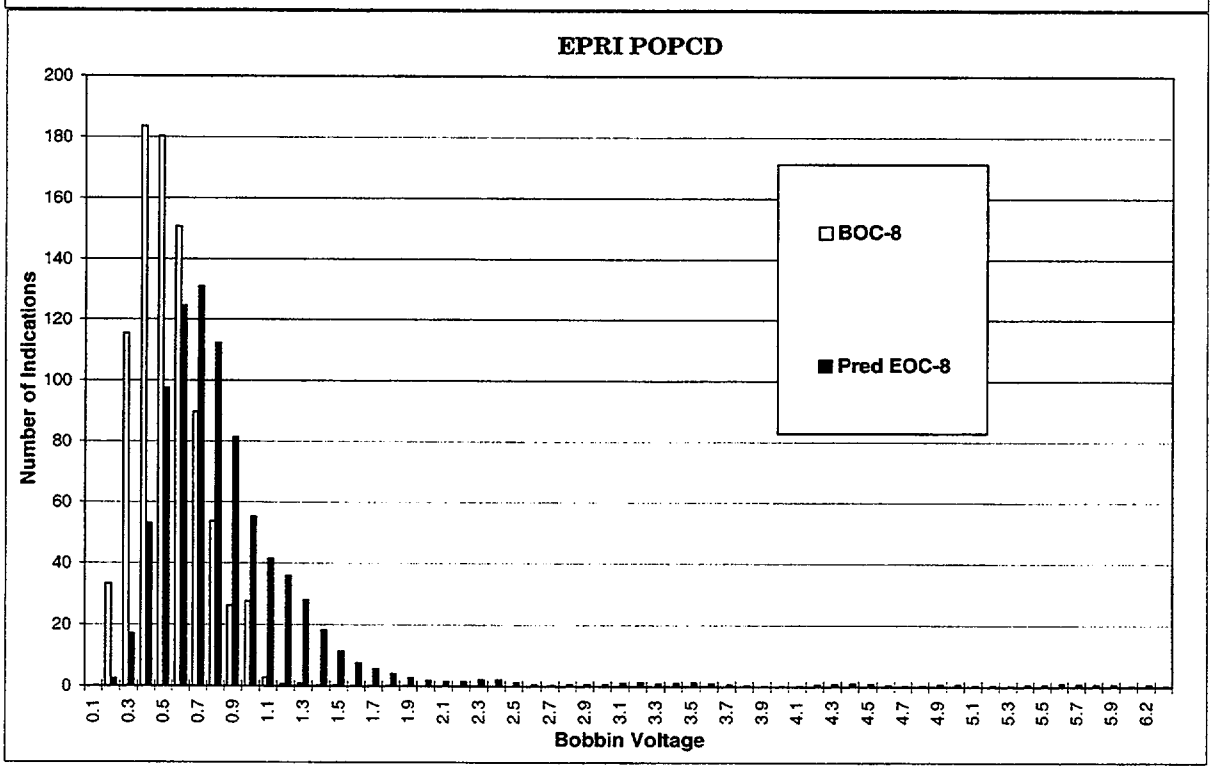


Figure 6-4
South Texas Unit 2 SG-D
Predicted Bobbin Voltage Distribution for Cycle 8

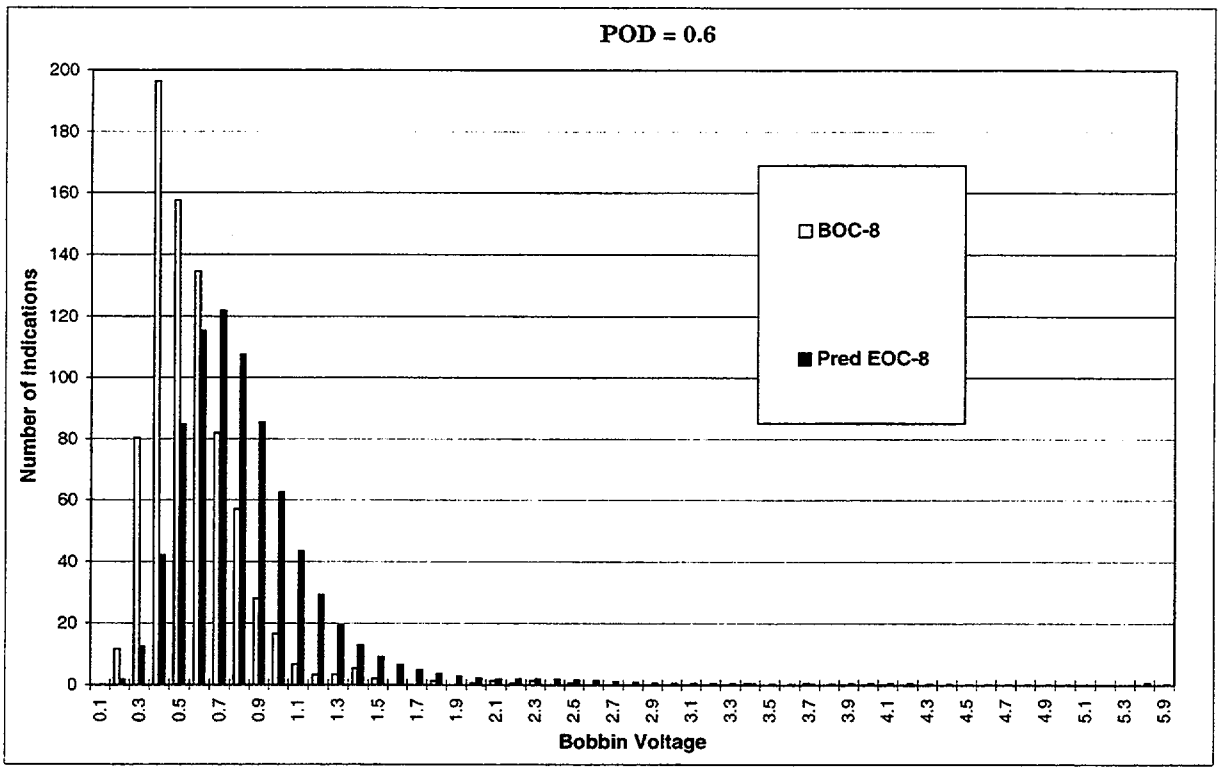


Figure 6-5
South Texas Unit 2 October 1999
Bobbin Voltage Distributions for Cycle 7

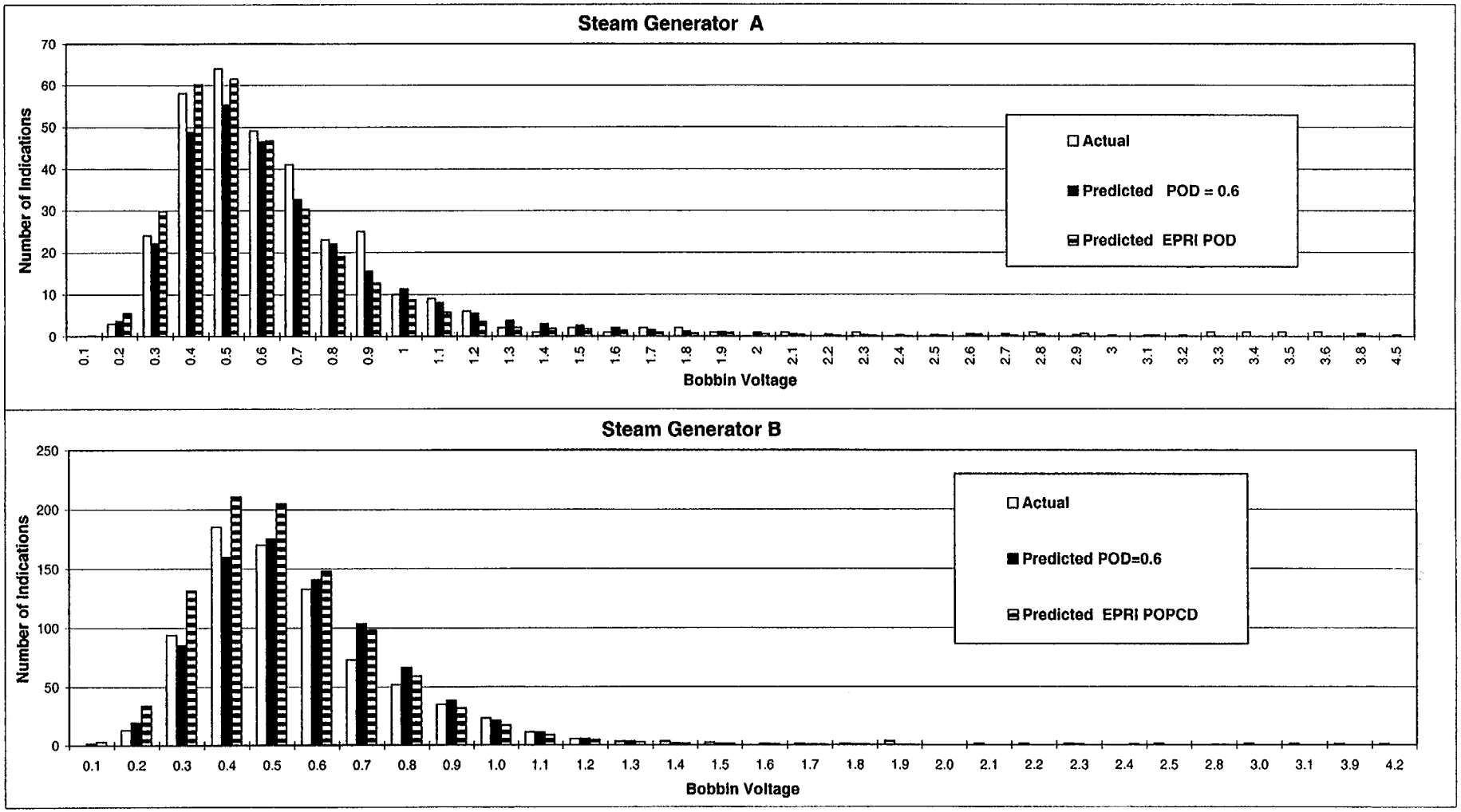
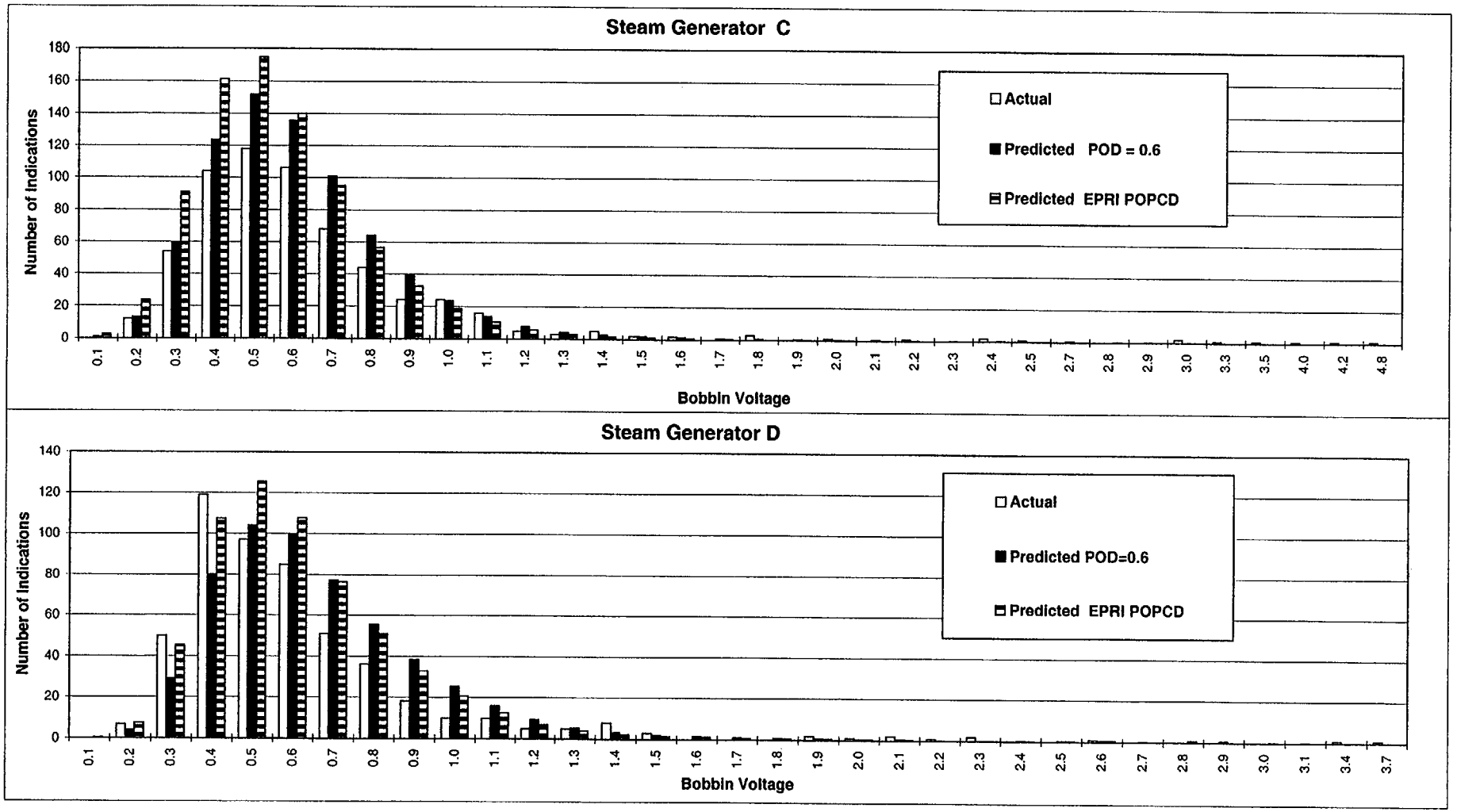


Figure 6-6
South Texas Unit 2 October 1999
Bobbin Voltage Distributions for Cycle 7



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7.0 SLB Leak Rate and Tube Burst Probability Analyses

This section presents the results of analyses carried out to predict the leak rates and tube burst probabilities for postulated SLB conditions using the actual voltage distributions from EOC-7 inspection as well as for the projected EOC-8 voltage distributions. The methodology used in these analyses is described in Section 6.0. SG-C with the largest number of indications over 1 volt at EOC-7 is expected to yield the limiting SLB leak rate and burst probability for Cycle 8.

7.1 Leak Rate and Tube Burst Probability for EOC-7

Analyses to calculate EOC-7 SLB leak rates and tube burst probabilities were performed using the actual bobbin voltage distributions presented in Table 6-2. The results of Monte Carlo calculations are summarized in Table 7-1. It is noted that while the EOC-7 projections utilized the leak and burst database presented in Addendum-2 to the EPRI database report (Reference 8-4), the latest database available then, the analysis for the actual EOC-7 conditions utilizes the updated Addendum-3 leak and burst database (Reference 8-5). The Addendum-3 database includes the latest (EOC-6) pulled tube leak and burst test data from South Texas Unit-2, and it was used for the EOC-7 analysis because it yields slightly more conservative results (by about 20% to 30%). A comparison of the EOC-7 actuals in Table 7-1 with the corresponding predictions presented in Reference 8-2, indicates the following.

a) SG-A was predicted to be the limiting steam generator for EOC-7 based on a voltage distribution projection performed using the EOC-6 outage. However, SG-C was found to have the highest tube leak rate and burst probability based on actual EC bobbin measurements for EOC-7.

b) Leak rate and tube burst probability predictions based on the EOC-6 inspection data are below those obtained with the actual measured EOC-7 voltages. However, the magnitude of the differences are small (~7×10^{-4} for burst probability and 0.14 gpm for leakage) in comparison to the acceptance criteria. One reason for the projected EOC-7 leak rates and burst probabilities underestimating the actuals is that the database used with the actual voltages yields higher leak and burst values. Another reason for underestimation of the EOC-7 actuals is that the actual growth rates during Cycle 7 were higher than those assumed in the EOC-7 projection analyses.

c) Leak rate and tube burst probability predictions for all four SGs based upon the EOC-7 actual bobbin measurements are about an order of magnitude below their respective acceptance limits.

In summary, the limiting values for SLB leak rate (0.14 gpm) and tube burst probability (1.5×10^{-3}) obtained using the actual measured voltages are about an order of magnitude below the allowable Cycle 8 SLB leakage limit of 15.4 gpm (room temperature) and the NRC reporting guideline of 10^{-2} for the tube burst probability.

7.2 Leak Rate and Tube Burst Probability for EOC-8

Calculations to predict SLB leak rate and tube burst probability for the EOC-8 condition were carried out for all SGs using the NRC required constant POD value of 0.6. For the limiting SG, SG-C, leak and burst projection was also performed using the voltage dependent EPRI POPCD distribution. The latest leak and burst correlations for ¾" tubes (based on the Addendum-3 data in Reference 8-5) were applied. The projected results for the EOC-8 conditions are summarized in Table 7-2. With the standard calculation methodology presented in Reference 8-3 and a constant POD of 0.6, the largest EOC-8 SLB leak rate projected is 0.48 gpm (room temperature), and it is predicted for SG-C which has the largest number of indications over 1 volt returned to service for Cycle 8 operation. This limiting SLB leak rate value is less than 1/30th of the allowable SLB leakage limit of 15.4 gpm (room temperature) for Cycle 8. The highest tube burst probability, also predicted for SG-C, is 6.4×10^{-3}, which is significantly less than the NRC reporting guideline of 10^{-2}. With EPRI POPCD, the projected EOC-8 leak rate and burst probability values for SG-C decrease by about 30% (relative to those for POD=0.6).

As noted in Section 3.2, a number of indications had a relatively large voltage growth (in excess of 2 volts) during Cycle 7. Although this growth behavior is likely be a one-time event, sensitivity analyses were performed to examine the impact of this growth trend continuing in Cycle 8. Leak and burst analysis for each SG was repeated using a conservative growth distribution based on SG-specific growth data plus the top 3 growth values for Cycle 7 (if they are not already a part of the SG-specific growth data). Also, EOC-8 leak rate and burst probability projections for SGs A and C (SGs with a growth distribution more limiting than the all SG composite growth distribution) were repeated taking into account the growth dependency on the BOC voltage. The results are summarized in Table 7-3. It is evident that the sensitivity analysis assumptions had the largest impact on SG-A. The reason being that none of the 3 largest growth values are

from the SG-A data, so they are additional data points added to the SG-A distribution. Since SG-A has the smallest indication population at EOC-7, the top 3 growth values have the highest probability of occurrence in the distribution applied for SG-A. The voltage-dependent growth assumption still yields a higher SLB leak rate and tube burst probability for SG-C than for SG-A. The limiting leak rate and burst probability calculated in these sensitivity analyses also meet the GL 95-05 requirements for Cycle 8 operation.

In summary, SLB leak rates and tube burst probabilities predicted for EOC-8 meet the GL 95-05 requirements for Cycle 8 operation.

Table 7-1
South Texas Unit 2 1999 EOC-7 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)
				1 Tube	1 or More Tubes	
EOC - 7 PROJECTIONS(2,3)						
A	0.6	293.3	4.5	4.2×10^{-4}	4.2×10^{-4}	3.3×10^{-2}
B		835.3	2.8	7.8×10^{-5}	7.8×10^{-5}	2.7×10^{-3}
C		749.3	2.9	8.8×10^{-5}	8.8×10^{-5}	5.2×10^{-3}
D		557.7	3.1	1.2×10^{-4}	1.2×10^{-4}	8.2×10^{-3}
A	POPCD	296.8	3.1	1.1×10^{-4}	1.1×10^{-4}	6.8×10^{-3}
B		957.6	2.8	5.8×10^{-5}	5.8×10^{-5}	2.5×10^{-3}
C		821.0	2.8	5.3×10^{-5}	5.3×10^{-5}	2.8×10^{-3}
D		608.1	3.0	3.1×10^{-5}	3.1×10^{-5}	6.4×10^{-3}
A(4)	0.6	293.30	4.5	5.5×10^{-4}	5.5×10^{-4}	4.5×10^{-2}
EOC - 7 ACTUALS(4)						
A	1	330	3.6	5.8×10^{-4}	5.8×10^{-4}	5.9×10^{-2}
B		815	4.2	8.1×10^{-4}	8.1×10^{-4}	7.2×10^{-2}
C		602	4.8	1.5×10^{-3}	1.5×10^{-3}	0.14
D		515	3.7	4.2×10^{-4}	4.2×10^{-4}	4.3×10^{-2}

Notes: (1) Adjusted for POD.
(2) Based on a Projected Cycle 7 length of 374 EFPD.
(3). Leak and burst database and correlations in Reference 8-4 (Addendum-2) applied
(4) Updated leak and burst database in Addendum-3 (Reference 8-5) including 1998 South Texas-2 pulled tube data applied.

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Table 7-2
South Texas Unit-2 October 1998 Outage
Summary of Projected Tube Leak Rate and Burst Probability
for EOC-8 - 250k Simulations

Steam Generator	POD	No. of Indic-ations(1)	Max. Volts(2)	Burst Probability		SLB Leak Rate (gpm)(3)	Comments
				1 Tube	1 or More Tubes		
EOC - 8 PROJECTIONS (Based on Cycle 8 Duration of 461 EFPD)							
A	0.6	509	5.8	2.4×10^{-3}	2.4×10^{-3}	0.22	Standard leak rate and tube burst probability methodology Addendum-3 (Reference 8-5) database
B		1294	6.0	4.5×10^{-3}	4.5×10^{-3}	0.37	
C		927	6.2	6.3×10^{-3}	6.4×10^{-3}	0.48	
D		792	5.9	2.7×10^{-3}	2.7×10^{-3}	0.25	
C	POPCD	866	6.0	4.4×10^{-3}	4.4×10^{-3}	0.35	

Notes
(1) Number of indications adjusted for POD.
(2) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
(3) Equivalent volumetric rate at room temperature.

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Table 7-3
South Texas Unit-2 October 1998 Outage
Sensitivity Analysis for Tube Leak Rate and Burst Probability
Projections for EOC-8 - 250k Simulations

Steam Generator	POD	No. of Indic-ations(1)	Max. Volts(2)	Burst Probability		SLB Leak Rate (gpm)(3)	Comments
				1 Tube	1 or More Tubes		
EOC - 8 PROJECTIONS (Based on Cycle 8 Duration of 461 EFPD)							
A	0.6	509	6.3	6.9×10^{-3}	6.9×10^{-3}	0.50	SG-specific growth distribution including 3 largest growth values for Cycle 7 Addendum-3 (Reference 8-5) database
B		1294	6.2	6.5×10^{-3}	6.5×10^{-3}	0.48	
C		927	6.3	7.9×10^{-3}	8.0×10^{-3}	0.56	
D		792	6.2	5.6×10^{-3}	5.6×10^{-3}	0.43	
A	POPCD	463	6.3	9.1×10^{-3}	9.2×10^{-3}	0.63	Voltage-dependent growth
C		866	6.3	9.7×10^{-3}	9.8×10^{-3}	0.68	

Notes
(1) Number of indications adjusted for POD.
(2) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
(3) Equivalent volumetric rate at room temperature

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8.0 References

8-1 NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," USNRC Office of Nuclear Reactor Regulation, August 3, 1995.

8-2 SG-99-01-002, "South Texas Unit-2, Cycle 7 Voltage-Based Repair Criteria Report," Westinghouse Electric Company, January 1999.

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 EPRI Report NP 7480-L, Addendum 2, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate repair Limits," Electric Power Research Institute, April 1998.

8-5 EPRI Report NP 7480-L, Addendum 3, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate repair Limits," Electric Power Research Institute, May 1999.

8-6 Letter from B. W. Sheron, Nuclear Regulatory Commission, to A. Marion, Nuclear Energy Institute, dated February 9, 1996.

8-7 Attachment to letter ST-WN-NOC-990087, "South Texas Project Unit-2, Steam Generator Degradation Assessment, 2RE07 Refueling Outage," Westinghouse Electric Company, August 1999.