

**BEAVER VALLEY UNIT - 1**  
**CYCLE 13 VOLTAGE-BASED REPAIR CRITERIA**  
**90-DAY REPORT**

March 1998



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**Beaver Valley Unit - 1**  
**Cycle 13 Voltage-Based Repair Criteria**  
**90-Day Report**

**1.0 Introduction**

This report provides a summary of the Beaver Valley Unit-1 steam generator (SG) bobbin and rotating pancake coil (RPC) probe inspections at tube support plate (TSP) intersections 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 13 as outlined in NRC Generic Letter 95-05 (Reference 8-1). Information required by the Generic Letter is provided in this report including SLB leak rates and tube burst probabilities calculated using the end of cycle (EOC) conditions for the recently completed cycle (Cycle 12) and projection of bobbin voltage distributions, leak rates and burst probabilities for the ongoing cycle (Cycle 13).

Analyses for Cycle 12 were carried out using the actual bobbin voltage distributions measured during the EOC-12 outage and the results compared with corresponding values from projections performed based on the last (EOC-11) bobbin voltage data (presented in Reference 8-2). These evaluations utilized the Westinghouse generic Monte Carlo methodology presented in Reference 8-3.

Analyses were also performed to project leak rates and tube burst probabilities for postulated SLB conditions at the end of the ongoing cycle (Cycle 13) based on the 2.0 volt repair criteria. These analyses utilized bobbin voltage distributions measured during the recent (EOC-12) inspection and a limiting growth rate distribution from the last two inspections (EOC-11 and EOC-12 inspections).

## 2.0 Summary and Conclusions

A total of 2910 axial outside diameter stress corrosion cracking (ODSCC) indications were found during the EOC-12 inspection in all three SGs combined, of which 853 were inspected with a RPC probe, and 670 were confirmed as flaws. The RPC confirmed indications included 244 indications above 1.0 volt. The largest number of bobbin indications, 1241 indications, were found in SG-A; 396 of those were inspected by RPC, and 309 were confirmed as flaws. Only three indications were found above 2 volts in all SGs combined, all located in SG-A, and confirmed by RPC. No circumferential indications, axial indications extending outside the TSP or volumetric-type signals were identified by RPC inspection at TSP distorted signal indication locations. RPC inspection of dented intersections also did not show any circumferential indications or primary water stress corrosion cracking (PWSCC).

SLB leak rate and tube burst probability analyses were performed for the actual EOC-12 bobbin voltage distributions as well as the projected EOC-13 bobbin voltage distributions. EOC-12 actual measured bobbin voltages are all lower than the projections performed using the EOC-11 outage bobbin voltage data and constant probability of detection (POD) of 0.6. The actual number of indications detected during the EOC-12 inspection for all SGs are also below their corresponding projections. The SLB leak rate and tube burst probability values based on the actual measured voltages show significant margins relative to their projected values. SG-B was predicted to be the limiting SG at EOC-12 as it had a slightly higher projected SLB leak rate and burst probability than SG-A; however, SG-A was found to be limiting based on the measured data.

For the actual EOC-12 bobbin voltage distributions, the largest SLB leak rate is calculated for SG-A, and its magnitude is 0.3 gpm with the leak rate correlation and 2.4 gpm without the leak rate correlation. This leak rate value is substantially lower than the current allowable SLB leakage limit of 8.0 gpm as well as the previous limit of 4.5 gpm. All leak rate values quoted are equivalent volumetric rates at room temperature. The limiting conditional tube burst probability based on the EOC-12 actual measured voltages,  $9.7 \times 10^{-5}$  also predicted for SG-A, is well below the NRC reporting guideline of  $10^{-2}$ . The leak rate and burst probability values based on the actual EOC-12 voltages are calculated using an updated alternate repair criteria (ARC) database that includes 1996 Plant A-2 and 1997 Plant A-1 pulled tube data. This database is applied as it yields a SLB leak rate more conservative than the current NRC approved database. The projected SG-A EOC-12 burst probability was  $1.2 \times 10^{-4}$  and the SLB leak rate was 4.3 gpm. These results exceed those obtained from the actual distributions even though the latter utilize a more conservative ARC database.

SLB leak rate and tube burst probability projections were also performed for the EOC-13 conditions. SG-A is again predicted to be the limiting SG, and the EOC-13 leak and burst results for all three SGs are well within their allowable limits. Based on the NRC mandated constant POD of 0.6, EOC-13 SLB leak rate for SG-A is projected to be 1.0 gpm (room temperature), which is an order of magnitude below the current licensed limit of 8.0 gpm (room temperature). This limiting leak rate is also based on the updated leak rate and tube burst database, and it utilizes a leak rate versus bobbin voltage correlation. Per Reference 8-10, the test for the significance of a leak rate correlation can now be based on the p-value for the slope of the leak rate correlation determined on a one-sided basis (as opposed to a two-sided basis used until now). The slope parameter p-value for the 7/8" tube leak rate data determined on a one-sided basis meets the 5% limit specified in Generic Letter 95-05; consequently, a leak rate correlation can now be applied for 7/8" tubes. The limiting burst probability, also calculated for SG-A, is  $1.9 \times 10^{-4}$ ; it is about two decades below the NRC reporting guideline of  $10^{-2}$ .

SLB leak rates were also calculated assuming that leak rate is independent of bobbin voltage as in the prior 90 day reports. The limiting EOC-13 leak rate thus predicted (6.4 gpm) is about 6 times of that obtained using the leak rate correlation; thus, there is margin even in the EOC-13 SLB leak rate projections based on the overly conservative methodology previously applied (no correlation).

Probability of prior cycle detection (POPCD) for the last (EOC-11) inspection was assessed using EOC-11 and EOC-12 inspection results, and the data strongly supports a voltage dependent POD substantially higher than the NRC mandated POD value of 0.6. POPCD exceeds 0.6 at about 0.6 volt and remains above 0.90 beyond 0.8 volt. The Beaver Valley-1 EOC-11 POPCD distribution is slightly better than the generic POPCD distribution presented in Reference 8-4.

The EOC-12 RPC confirmation rate for RPC no detectable degradation (NDD) indications left in service during Cycle 12 is only about 27%, which is well below the conservative 70% value applied to RPC NDD indications in the leak and burst projections for Beaver Valley Unit-1. EOC-13 projections presented in this report were obtained including 70% of RPC NDD indications.

### 3.0 EOC-12 Inspection Results and Voltage Growth Rates

#### 3.1 EOC-12 Inspection Results

According to the guidance provided by NRC Generic Letter 95-05, the EOC-12 inspection of the Beaver Valley Unit-1 SGs consisted of a complete, 100% eddy current (EC) bobbin probe full length examination of the tube bundles in all three SGs. A 0.720 inch diameter probe was used for all hot and cold leg TSPs where voltage-based repair criteria were applied. Subsequently, RPC examination was performed for a minimum of 20 percent of the hot leg indications with amplitude between 1 and 2 volts, and all hot leg indications with an amplitude 2 volts and above. Only three indications were found above 2 volts in all three SGs combined, all located in SG-A; they were confirmed by RPC and removed from service. No ODSCC indications were found on the cold leg side at the TSPs. There were no circumferential indications at the TSPs, and no indications extending outside the TSPs. All bobbin indications at TSPs with potential inside diameter (ID) phase angles were examined with RPC and demonstrated to be outside diameter (OD) in origin. Dents 2 volts or larger on the hot leg side of the first three TSPs and all other TSP dents over 5 volts were also inspected with RPC; no circumferential or PWSCC indications were detected.

A summary of the EC indications for all three 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 13 operation are determined by the difference between the observed indications and the indications removed from service. No tubes were unplugged in the current inspection with the intent of returning them to service after inspection in accordance with the ARC.

Overall, the combined data for all three SGs of Beaver Valley Unit-1 show the following:

- Out of a total of 2910 TSP indications identified during the inspection, a total of 853 were RPC inspected.
- Of the 853 RPC inspected, 670 were RPC confirmed.
- Only three indications exceeded the 2 volt repair limit, all in SG-A.
- A total of 2831 indications were returned to service for Cycle 13 operation.

A review of Table 3-1 indicates that more indications (a quantity of 1198, with 108 indications above 1.0 volt) were returned to service in SG-A than the other SGs; thereby it potentially will be the limiting SG at EOC-13. It is noted that SG-A had all three indications above 2 volts found in the EOC-12 inspection.

Figure 3-1 shows the actual bobbin voltage distribution determined from the EOC-12 EC inspection; Figure 3-2 shows the population distribution of those EOC-12 indications removed from service due to tube repairs; Figure 3-3 shows the distribution for indications returned to service for Cycle 13 operation. Of the 79 indications removed from service, only 3 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 .

The distribution of EOC-12 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 (2765 out of 2910 indications occurred at the hot leg intersections in the first three TSPs), although the mechanism extended to higher TSPs. No indications were detected on the cold leg side. This distribution indicates the predominant temperature dependence of ODSCC at Beaver Valley Unit-1, 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 13 operation, voltage growth rates were developed from EOC-12 (October 1997) inspection data and a reevaluation of the EOC-11 (April 1996) inspection EC signals for the same indications. Table 3-3 shows the cumulative probability distribution for growth rate in each Beaver Valley Unit-1 steam generator during Cycle 12 (May '96 - September '97) on an EFPY basis, along with the corresponding Cycle 11 growth rate distributions. Cycle 12 growth data are also plotted in Figure 3-5. The curve labeled 'cumulative' in Figure 3-5 represents averaged composite growth data from all three SGs.

Average growth rates for each SG during Cycle 12 are summarized in Table 3-4, and all three SGs show a negative average growth value. The average growth rates over the entire voltage range vary between -19.2 % and -9.8% (of the BOC voltage) per EFPY, between SGs, with an overall average of -14.4% per EFPY. SG-B had the lowest growth (actually negative growth) among the three SGs, which explains why SG-B was not the limiting SG although it was projected to be limiting based on the prior cycle voltage data.

The extent of negative growth rates found for Cycle 12 is unusual for ARC applications and potential contributing factors were reviewed. Since the negative growths are consistent across all SGs, the potential cause is judged to be independent of the SG inspected. After evaluating several potential contributing factors, it was concluded that the calibration technique used during the EOC-11 inspection to normalize the bobbin voltages had resulted in overestimation of the EOC-11 bobbin voltages by about 12.6%. Additional details on the evaluation carried out to investigate causative factors for apparent large negative growths are provided at the end of this section.

The cumulative probability growth distributions (CPDFs) for Cycles 11 and 12 and the average growth rates for the two cycles were reevaluated after reducing all EOC-11 voltages by 12.6%. Tables 3-5 and 3-6 respectively show the revised CPDFs for Cycles 11 and 12 on an EFPY basis and the average growth rates for the three SGs. With the adjusted EOC-11 voltages, growth rates for Cycle 12 increase and Cycle 11 growths decrease: the average Cycle 12 growth rate of -16.3% before adjustment (Table 3-4) becomes about -3.8% after adjustment (Table 3-6), and the average Cycle 11 growth rate changes from 13.5% to about -0.9%. The CPDFs based on the growth data from all 3 SGs for Cycles 11 and 12 before and after adjusting the EOC-11 voltages are compared in Figure 3-6. Tables 3-7 and 3-8 respectively show the growth statistics for the last six operating periods with and without adjustment to the EOC-11 bobbin voltages. While the data in Table 3-7 indicate an abrupt rise and then a sudden drop in the growth rates for the last two cycles, the data in Table 3-8 show a more believable trend of progressively decreasing growth rates over the last six cycles. Therefore, the adjusted EOC-11 voltages provide a better representation of the growth rates.

The guidelines in Generic Letter 95-05 require the use of more conservative growth rate distributions from the past two inspections for projecting EOC distributions for the next operating cycle. It is evident from Figure 3-6 that the composite growth rates during Cycle 11 are higher than those during Cycle 12 with or without adjustment to the EOC-11 bobbin voltages. Therefore, Cycle 11 provides the more limiting cumulative probability distribution for growth for the last two cycles, and that growth distribution was used to develop EOC-13 predictions. Cycle 11 growth rates for SG-B are higher than the composite growth rates and, per the methodology presented in Reference 8-3, SG-specific growth rates are to be used for SG-B while the composite growth rates should be applied for the other two SGs. Although Cycle 11 growth rates based on the adjusted EOC-11 voltages are believed to be more realistic, unadjusted Cycle 11 growth rates shown in Table 3-3 were conservatively applied to obtain EOC-13 predictions.

During the prior two outages, (EOC-10 and EOC-11 outages), many tubes plugged earlier were deplugged and those meeting the current voltage based repair criteria were returned

to service. Recently, another plant with 7/8" diameter SG tubes experienced a significantly higher growth among deplugged tubes returned to service (in comparison to active tubes). To examine the growth trends for deplugged tubes returned to service in Beaver Valley Unit-1, growth rates for the last two cycles were calculated separately for deplugged tubes and active tubes, and these results are included in Table 3-9. The average growth values shown are based on adjusted EOC-11 voltages as they are believed to be more realistic. Table 3-9 includes the following data:

- 1) Two sets of growth data for the first cycle of operation after deplugged tubes are returned to service.
- 2) Growth rates for two consecutive cycles of operation for deplugged tubes returned to service.

Deplugged tubes returned to service in SG-B for Cycle 11 operation and those returned to service in SG-A for Cycle 12 operation had higher growth rates than the tubes active in the prior cycle, although the absolute growth is small for all SGs. On the basis of composite data from all SGs, deplugged tubes returned to service for Cycle 11 operation show a slightly higher growth rate (in comparison to active tubes) whereas the deplugged tubes returned to service for Cycle 12 operation do not show such an effect. Growth rates during the second cycle of operation for deplugged tubes returned to service during Cycle 11 are less than those for the corresponding active tubes. Thus, the data suggests that growth rate increase noted in the first cycle of operation (after the return to service) is temporary. No deplugged tubes were returned to service during the EOC-12 outage.

Table 3-10 lists the top 30 indications on the basis of Cycle 12 growth rates in descending order, and the data confirms that Cycle 12 had only modest growth. The growth values shown in this table are based on the adjusted EOC-11 voltages discussed above. All but 5 of the indications shown were RPC confirmed, but they are all below the 2 volt repair limit. Seven of the 30 indications shown are new indications, and EOC-11 voltages used to estimate growth rates for them were obtained by reevaluating the last inspection data; they are all relatively small indications.

Recently, some plants with 3/4" SG tubing experienced growth rates that demonstrated a potential dependency on the BOC voltages of previously identified indications. Such a growth behavior was observed after the repair limit for TSP indications was increased from 1 volt to 3 volts and, consequently, a significant number of indications with a BOC voltage between 1 volt to 3 volts were left in service for the first time in the plant history.

Large growths were observed primarily in indications with a BOC voltage over 1.5 volts. To determine if Beaver Valley Unit-1 exhibited a similar trend, growth rate data for Cycle 12 (based on adjusted EOC-11 voltages) were plotted against BOC voltage, and the resulting plot is shown in Figure 3-7. It is evident from Figure 3-7 that Cycle 12 growth data do not show any trend to increase with BOC voltage. The trend, if any, is for growth to decrease with BOC voltage; however, the growth rates are too small (negative average) to conclude that growth is decreasing with BOC voltage.

#### *Assessment of Potential Causative Factors for Large Negative Growth in Cycle 12*

The extent of negative growth rates found for Cycle 12 is unusual for ARC applications and potential contributing factors were reviewed. Since the negative growths are consistent across all SGs, the potential cause is judged to be independent of the SG inspected. Conceptual causes would then be expected to relate to either a uniform difference in bobbin probes or the voltage normalization technique applied to all SGs. Potential normalization issues could then be a problem in setting the voltage normalizations or a problem with the cross calibration of the standards to the reference laboratory calibration standard. The analysis setup of the voltage normalizations is always overchecked between the setups for the field and the voltage growth analyses. The voltage growth analyses yielded essentially the same bobbin voltages as the field analyses and the field voltage setup is not considered to be a contributor to the negative growths.

Different bobbin probes were used in the two inspections. Zetec 720-ULC probes were used in the EOC-12 inspection and Westinghouse long life probes in the EOC-11 inspection. Both probes have been used extensively in field inspections with no apparent differences between the probes. As an additional check, both probes were compared by setting the reference voltage on the 20% holes of a transfer standard and measuring the 20% hole voltages on another standard. No differences were found in the voltages and it is further concluded that the difference in probes does not significantly contribute to the negative growth rates.

New ASME calibration standards were used in the EOC-12 inspection. These new standards were cross calibrated to the reference laboratory standard using the Beaver Valley transfer standard (standard cross calibrated to the laboratory standard). The setup voltages for the 400/100 kHz mix were obtained by establishing the transfer standard to its cross calibrated value and measuring the mix voltage for each new standard. The resulting mix voltage for each standard was then used to normalize voltages for each standard in the bobbin coil field analyses.

A different cross calibration procedure was applied for the ASME standards used in the EOC-11 inspection. For these standards, the setup voltages for the 400/100 kHz mix were obtained by: establishing the transfer standard to its cross calibrated value at 400 kHz, measuring the 400 kHz voltage on the new standard and applying the Save/Store option to obtain the 400/100 kHz mix voltage for the new standard. The resulting mix voltage for each standard was then used to normalize voltages for each standard in the bobbin coil field analyses as consistently applied in ARC inspections. These two calibration techniques are equivalent if the ratio of 400/100 to 400 kHz voltages are the same between the reference laboratory standard, the transfer standard and the new standard. To assess this difference between techniques, the bobbin data for the latter transfer and field standards were reevaluated based on setting all transfer and new standard voltages in the mix channel. It was found that the use of the 400 kHz cross calibration technique resulted in about 12.6% (up to 1.2% difference between standards) higher setup voltages for the mix channel than use of the 400/100 kHz cross calibration technique.

Based on the above, the bobbin voltages for the EOC-11 inspection are about 12.6% high. Average growths were reevaluated for Cycles 11 and 12 based on reducing all EOC-11 voltages by 12.6%. When this adjustment is applied to all EOC-11 voltages, the negative Cycle 12 growth rate of -16.3% (Table 3-4) becomes about -3.8% (Table 3-6) and the Cycle 11 growth rate changes from 13.5% to about -0.9%. It is concluded that the reduced EOC-11 voltages represent an improved cross calibration to the laboratory standard and provide a better representation of the growth rates. The growth rates for the last two cycles at Beaver Valley-1 show very small growth which is consistent with the 3% growth seen for Cycle 10 (Table 3-7).

Similar differences were found between the two cross calibration techniques when additional standards were evaluated. It appears that the reference laboratory standard has a higher ratio of 400/100 to 400 kHz voltages than typical of many other standards. Since voltages in the ARC database are based on mix voltages traceable to the reference laboratory calibration standard mix voltage, the most appropriate cross calibration procedure is to setup all voltages on transfer and new standards in the mix channel.

### 3.3 NDE Uncertainties

The non-destructive examination (NDE) uncertainties applied for the Cycle 12 voltage distributions in the Monte Carlo analyses for leak rate and burst probabilities are the same as those previously reported in the Beaver Valley Unit-1 voltage-based repair criteria report of Reference 8-2 and NRC Generic Letter 95-05 (Reference 8-1). The probe wear uncertainty has



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-12 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 1997 EOC-12 indications not RPC inspected since inclusion for the EOC-11 inspection could increase POPCD by including indications on a tube plugged for non-ODSCC causes which could have RPC NDD indication. In addition, the objective of using RPC confirmation for POPCD is to distinguish detection of indications at EOC<sub>n-1</sub> that could contribute to burst at EOC<sub>n</sub> so that the emphasis is on EOC<sub>n</sub> RPC confirmation. This POPCD can be obtained by replacing the EOC-12 RPC confirmed by RPC confirmed plus not RPC inspected in the above definition of POPCD. For this report, both POPCD definitions are evaluated for Beaver Valley Unit-1.

The POPCD evaluation for the 1996 EOC-11 inspection data is shown on Figure 3-8 and summarized in Table 3-11. Since there are only 3 indications in 2 to 2.5 volts bin, they were combined with those in 1.5 to 2 volts bin in Figure 3-8. A generic POPCD distribution developed by analyzing data from 15 inspections in 8 plants, presented in Table 7-4 of Reference 8-4, is also shown in Figure 3-8. For voltages above about 0.6 volt, EOC-11 POPCD values are substantially higher than the NRC mandated POD value of 0.6, and they remain above 0.90 beyond 0.8 volt.

In summary, the Beaver Valley Unit-1 EOC-11 POPCD strongly supports a voltage dependent POD substantially higher than the NRC mandated POD value of 0.6 above about 0.6 volts and approaching unity at about 2.5 volts, and it is in good agreement with the generic POPCD distribution presented in Reference 8-4

### 3.5 Assessment of RPC Confirmation Rates

This section tracks the 1996 EOC-11 indications left in service at BOC-12 relative to RPC inspection results in 1997 at EOC-12. Composite results for all SGs are given in Table 3-12. For 1996 bobbin indications left in service, the indications are tracked relative to 1996 RPC confirmed, 1996 RPC NDD, 1996 bobbin indications not RPC inspected and 1996 bobbin indications with no indication found in 1997. Also included are new 1997 indications. The table shows, for each category of indications, the number of indications RPC inspected and RPC confirmed in 1997 as well as the percentage of RPC confirmed indications.

Out of a total of 35 RPC NDD indications from all three SGs left in service in 1996, 11 were RPC tested in 1997 and 3 of those were confirmed. Thus, the overall RPC confirmation rate for 1996 RPC NDD indications is 27.3 %. This overall confirmation rate is significantly below that found for RPC NDD indications tested in last two inspections. (60% in 1996 and 50.9% in 1995), and it is the same as that found for 1991 RPC NDD indications RPC tested in 1993 (27.2%). For successive ARC inspections at other plants, the confirmation rate for RPC NDD indications left in service was typically < 40%.

The NRC Safety Evaluation Report (SER) for Beaver Valley-1 (Reference 8-5) allows for consideration of only a fraction of RPC NDD indications from the current inspection in establishing the BOC voltage distribution for the next cycle. The fractional value applicable is the largest RPC confirmation rate for prior cycle RPC NDD indications found during the last two outages, but it may not be less than 0.7. Thus, the fraction that can be applied for 1996 RPC NDD indications is 0.7.

### 3.6 Probe Wear Criteria

An alternate probe wear criteria approved by the NRC (Reference 8-6) was applied during the EOC-12 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 inspected since the last successful probe wear check be reinspected with a good probe. As the repair limit for Beaver Valley Unit-1 is 2 volts, all tubes containing indications for which the worn probe voltage is above 1.5 volts are to be inspected with a new probe. A total of 13 indications with a bobbin voltage above 1.5 volts were found in the calibration groups that failed probe wear checks, and the tubes containing those indications were reinspected with a new probe (Reference 8-7). No new indications were indicated during reinspection with a new probe, and no indications had its voltage increase above the repair limit when reinspected with a good probe. For indications with a worn probe voltage above 1.5 volts, the average difference between the worn and new probe voltages was only -0.09 volt.

As required by Reference 8-6, the number of new indications detected in the present inspection in tubes which were inspected with a worn probe in the last inspection was also determined. Out of a total of 624 new indications found in the current inspection, only 61 are in tubes inspected with a worn probe in the last inspection, which is not considered a disproportionate number of indications since they were found in a tube population making up 10 calibration groups. Also, actual indication population distributions from the current inspection were compared against the projected distributions based on the prior cycle data presented in Reference 8-2, and the projections were found to be conservative (see Section 6.0 for details). Thus, the requirements specified in Reference 8-6 for applying the alternate probe wear criteria are met.

**Table 3-1**  
**Beaver Valley Unit-1 October 97 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				Cycle - 13 All Tubes Returned to Service	In-Service During Cycle				Cycle - 13 All Tubes Returned to Service
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired		Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	
0.1	0	0	0	0	0	1	1	1	0	1
0.2	43	4	1	1	42	41	5	1	3	38
0.3	144	17	10	4	140	137	11	10	3	134
0.4	228	32	16	5	223	189	20	10	5	184
0.5	205	26	15	9	196	134	19	12	7	127
0.6	159	33	22	4	154	120	9	7	5	115
0.7	138	22	15	2	137	93	17	13	1	92
0.8	78	40	33	1	77	57	29	26	2	55
0.9	80	64	55	1	79	41	34	30	0	41
1	45	40	36	3	42	26	26	25	1	25
1.1	31	31	25	2	29	25	25	23	0	25
1.2	23	23	22	1	22	20	18	16	0	20
1.3	22	22	18	2	20	10	10	10	0	10
1.4	8	7	7	1	7	6	6	5	0	6
1.5	14	13	13	2	12	5	5	5	0	5
1.6	7	7	6	1	6	4	4	3	0	4
1.7	6	6	6	1	5	3	3	3	0	3
1.8	3	3	3	0	3	1	1	1	0	1
1.9	4	3	3	0	4	0	0	0	0	0
2.1	1	1	1	1	0	0	0	0	0	0
2.5	2	2	2	2	0	0	0	0	0	0
Total	1241	396	309	43	1198	913	243	201	27	886
> 1v	121	118	106	13	108	74	72	66	0	74
> 2v	3	3	3	3	0	0	0	0	0	0

Voltage Bin	Steam Generator C					Composite of All Steam Generators				
	In-Service During Cycle				Cycle - 13 All Tubes Returned to Service	In-Service During Cycle				Cycle - 13 All Tubes Returned to Service
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired		Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	
0.1	0	0	0	0	0	1	1	1	0	1
0.2	54	11	1	0	54	138	20	3	4	134
0.3	96	12	4	3	93	377	40	24	10	367
0.4	108	24	15	2	106	525	76	41	12	513
0.5	117	30	19	1	116	456	75	46	17	439
0.6	105	25	17	1	104	383	67	46	10	373
0.7	67	15	12	0	67	299	54	40	3	296
0.8	53	12	9	1	52	188	81	68	4	184
0.9	35	4	3	0	35	156	102	88	1	155
1	35	9	8	0	35	106	75	69	4	102
1.1	16	9	9	0	16	72	65	57	2	70
1.2	22	19	19	1	21	65	60	57	2	63
1.3	15	14	14	0	15	47	46	42	2	45
1.4	11	9	9	0	11	25	22	21	1	24
1.5	12	11	11	0	12	31	29	29	2	29
1.6	5	5	5	0	5	16	16	14	1	15
1.7	2	2	2	0	2	11	11	11	1	10
1.8	1	1	1	0	1	5	5	5	0	5
1.9	2	2	2	0	2	6	5	5	0	6
2.1	0	0	0	0	0	1	1	1	1	0
2.5	0	0	0	0	0	2	2	2	2	0
Total	756	214	160	9	747	2910	853	670	79	2831
> 1v	86	72	72	1	85	281	262	244	14	267
> 2v	0	0	0	0	0	3	3	3	3	0

**Table 3-2**  
**Beaver Valley Unit-1 October 1997**  
**TSP ODSCC Indication Distributions for Tubes in Service During Cycle 12**  
**(Based on Unadjusted EOC-11 Voltages)**

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	699	2.47	0.62	0.96	-0.07	498	1.80	0.60	0.16	-0.17
2H	411	1.75	0.55	0.39	-0.08	263	1.31	0.49	0.36	-0.12
3H	86	1.60	0.56	0.32	-0.06	84	1.16	0.44	0.13	-0.11
4H	26	1.22	0.53	0.38	-0.01	52	0.96	0.41	0.06	-0.14
5H	14	1.19	0.41	0.12	-0.04	13	0.58	0.33	0.02	-0.07
6H	3	0.57	0.38	-0.03	-0.07	2	0.34	0.24	-0.18	-0.20
7H	2	0.30	0.23	-0.01	-0.05	1	0.29	0.29	-0.06	-0.06
Total	1241					913				
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	412	1.86	0.66	0.45	-0.14	1609	2.47	0.62	0.96	-0.12
2H	238	1.61	0.53	0.22	-0.12	912	1.75	0.53	0.39	-0.10
3H	74	1.16	0.44	0.16	-0.08	244	1.60	0.48	0.32	-0.08
4H	14	1.35	0.53	0.03	-0.14	92	1.35	0.46	0.38	-0.10
5H	14	0.42	0.23	0.03	-0.08	41	1.19	0.33	0.12	-0.06
6H	4	0.40	0.31	0.04	-0.04	9	0.57	0.32	0.04	-0.08
7H	0	-	-	-	-	3	0.30	0.25	-0.01	-0.05
Total	756					2910				

Table 3-3  
 Beaver Valley Unit-1 October 1997  
 Signal Growth Statistics For Cycle 12 on an EPFY Basis  
 (Based on Unadjusted EOC-11 Voltages)

Delta Volts	Steam Generator A			Steam Generator B			Steam Generator C			Cumulative		
	Cycle 11		Cycle 12		Cycle 11		Cycle 12		Cycle 11		Cycle 12	
	CPDF <sup>#</sup>	No. of Inds	CPDF <sup>#</sup>	No. of Inds	CPDF <sup>#</sup>	No. of Inds	CPDF <sup>#</sup>	No. of Inds	CPDF <sup>#</sup>	No. of Inds	CPDF <sup>#</sup>	No. of Inds
-0.6	0.0	0	0.0	0	0.0	0.0	0	0.001	1	0.0	1	0.0
-0.5	0.0	1	0.001	0	0.0	0.0	0	0.001	0	0.0	1	0.001
-0.4	0.002	2	0.002	18	0.02	0.0	6	0.009	6	0.001	26	0.01
-0.3	0.006	24	0.022	70	0.096	0.0	25	0.042	25	0.003	119	0.051
-0.2	0.021	87	0.092	155	0.266	0.003	126	0.209	126	0.01	368	0.177
-0.1	0.071	347	0.371	317	0.613	0.031	263	0.557	263	0.04	927	0.496
0	0.313	501	0.775	255	0.893	0.229	242	0.877	242	0.231	998	0.838
0.1	0.769	220	0.952	81	0.981	0.692	75	0.976	75	0.657	376	0.968
0.2	0.939	43	0.987	15	0.998	0.884	15	0.996	15	0.863	73	0.993
0.3	0.976	11	0.996	1	0.999	0.969	2	0.999	2	0.95	14	0.998
0.4	0.994	3	0.998	1	1.0	0.997	1	1.0	1	0.982	5	0.999
0.5	0.999	0	0.998	0	1.0	1.0	0	1.0	0	0.994	0	0.999
0.6	1.0	0	0.998	0	1.0	1.0	0	1.0	0	0.998	0	0.999
0.7	1.0	0	0.998	0	1.0	1.0	0	1.0	0	0.999	0	0.999
0.8	1.0	1	0.999	0	1.0	1.0	0	1.0	0	0.999	1	0.9997
0.9	1.0	1	1.0	0	1.0	1.0	0	1.0	0	1.0	1	1.0
Total		1241		913			756				2910	

<sup>#</sup> CPDF = Cumulative probability distribution function

**Table 3-4**  
**Beaver Valley Unit-1 - October 1997 Outage**  
**Average Voltage Growth During Cycle 12**  
**(Based on Unadjusted EOC-11 Voltages)**

Voltage Range	Number of Indications	Average Voltage		Average Voltage Growth		Percent Growth	
		BOC	EOC	Entire Cycle	Per EFPY *	Entire Cycle	Per EFPY *
<b>Composite of All Steam Generator Data</b>							
Entire Voltage Range	2910	0.68	0.68	-0.111	-0.098	-16.3%	-14.4%
V <sub>BOC</sub> < .75 Volts	1904	0.48	0.48	-0.076	-0.067	-15.8%	-13.9%
≥ .75 Volts	1006	1.06	1.06	-0.178	-0.157	-16.8%	-14.8%
<b>Steam Generator A</b>							
Entire Voltage Range	1241	0.66	0.66	-0.073	-0.065	-11.1%	-9.8%
V <sub>BOC</sub> < .75 Volts	856	0.48	0.48	-0.053	-0.046	-11.0%	-9.6%
≥ .75 Volts	385	1.05	1.05	-0.119	-0.105	-11.3%	-10.0%
<b>Steam Generator B</b>							
Entire Voltage Range	913	0.69	0.69	-0.150	-0.132	-21.8%	-19.2%
V <sub>BOC</sub> < .75 Volts	589	0.48	0.48	-0.098	-0.086	-20.4%	-18.0%
≥ .75 Volts	324	1.06	1.06	-0.243	-0.214	-22.9%	-20.2%
<b>Steam Generator C</b>							
Entire Voltage Range	756	0.71	0.71	-0.127	-0.112	-17.8%	-15.7%
V <sub>BOC</sub> < .75 Volts	459	0.48	0.48	-0.091	-0.080	-18.9%	-16.6%
≥ .75 Volts	297	1.07	1.07	-0.183	-0.161	-17.1%	-15.1%

# Based on Cycle 12 duration of 415.4 EFPD (1.137 EFPY)

**Table 3-5**  
**Beaver Valley Unit-1 October 1997**  
**Signal Growth Statistics For Cycle 12 on an EPY Basis**  
**Based on ECC-11 Bobbin Voltages Multiplied by 0.874 for Calibration Adjustment**

Delta Volts	Steam Generator A			Steam Generator B			Steam Generator C			Cumulative		
	Cycle 11	Cycle 12		Cycle 11	Cycle 12		Cycle 11	Cycle 12		Cycle 11	Cycle 12	
	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF
-0.5	0.004	0	0.0	0.0	0	0.0	0.0	0	0.0	0.002	1	0.0
-0.4	0.006	0	0.0	0.0	0	0.0	0.0	1	0.001	0.003	1	0.0
-0.3	0.019	1	0.001	0.012	11	0.079	0.003	3	0.005	0.009	15	0.005
-0.2	0.066	24	0.02	0.079	61	0.337	0.023	26	0.04	0.035	111	0.044
-0.1	0.249	148	0.139	0.337	236	0.749	0.154	361	0.517	0.167	745	0.3
0	0.681	465	0.514	0.749	376	0.949	0.584	272	0.877	0.565	1113	0.682
0.1	0.942	448	0.875	0.949	182	0.99	0.9	75	0.976	0.872	705	0.924
0.2	0.984	108	0.962	0.99	38	0.997	0.979	15	0.996	0.964	161	0.98
0.3	0.996	31	0.987	0.997	6	0.999	1.0	2	0.999	0.989	39	0.993
0.4	1.0	12	0.997	0.999	2	1.0	1.0	1	1.0	0.997	15	0.998
0.5		2	0.998	1.0	1	1.0	1.0	0	1.0	0.999	3	0.999
0.6		0	0.998	1.0	0	1.0	1.0	0	1.0	0.999	0	0.999
0.7		0	0.998	1.0	0	1.0	1.0	0	1.0	1.0	0	0.999
0.8		0	0.998	1.0	0	1.0	1.0	0	1.0	1.0	0	0.999
0.9		1	0.999	1.0	0	1.0	1.0	0	1.0	1.0	1	0.9997
1		1	1.0	1.0	0	1.0	1.0	0	1.0	1.0	1	1.0
Total		1241			913			756			2911	

**Table 3-6**  
**Beaver Valley Unit-1 - October 1997 Outage**  
**Average Voltage Growth During Cycle 12**  
**(Based on EOC-11 Bobbin Voltages Multiplied by 0.874 for Calibration Adjustment)**

Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Percent Growth	
			Entire Cycle	Per EFPY *	Entire Cycle	Per EFPY *
<b>Composite of All Steam Generator Data</b>						
Entire Voltage Range	2910	0.60	-0.025	-0.022	-4.3%	-3.8%
V <sub>BOC</sub> < .75 Volts	2181	0.46	-0.020	-0.017	-4.4%	-3.8%
≥ .75 Volts	729	1.01	-0.042	-0.037	-4.1%	-3.6%
<b>Steam Generator A</b>						
Entire Voltage Range	1241	0.58	0.010	0.008	1.7%	1.5%
V <sub>BOC</sub> < .75 Volts	954	0.45	0.007	0.006	1.6%	1.4%
≥ .75 Volts	287	1.00	0.017	0.015	1.7%	1.5%
<b>Steam Generator B</b>						
Entire Voltage Range	913	0.60	-0.063	-0.056	-10.5%	-9.3%
V <sub>BOC</sub> < .75 Volts	680	0.46	-0.046	-0.040	-10.0%	-8.8%
≥ .75 Volts	233	1.02	-0.114	-0.101	-11.2%	-9.9%
<b>Steam Generator C</b>						
Entire Voltage Range	756	0.62	-0.037	-0.033	-6.0%	-5.3%
V <sub>BOC</sub> < .75 Volts	547	0.46	-0.035	-0.031	-7.6%	-6.7%
≥ .75 Volts	209	1.03	-0.042	-0.037	-4.1%	-3.6%

# Based on Cycle 12 duration of 415.4 EFPD (1.137 EFPY)

**Table 3-7**  
**Beaver Valley Unit-1 October 1997**  
**Average Voltage Growth for Cycle 12**  
**Composite of All Steam Generator Data**  
**(Based on Unadjusted EOC-11 Voltages)**

Bobbin Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Average Percentage Growth	
			Entire Cycle	Per EFPY	Entire Cycle	Per EFPY
<b>Cycle 12 (1996 - 1997) - 415.4 EFPD</b>						
Entire Voltage Range	2910	0.68	-0.111	-0.098	-16.3%	-14.4%
V <sub>BOC</sub> < .75 Volts	1904	0.48	-0.076	-0.067	-15.8%	-13.9%
≥ .75 Volts	1006	1.06	-0.178	-0.157	-16.8%	-14.8%
<b>Cycle 11 (1995 - 1996) - 352.94 EFPD</b>						
Entire Voltage Range	1936	0.60	0.080	0.083	13.5%	13.9%
V <sub>BOC</sub> < .75 Volts	1434	0.48	0.076	0.078	15.9%	16.5%
≥ .75 Volts	502	0.94	0.093	0.096	9.9%	10.2%
<b>Cycle 10 (1993 - 1995) - 435.79 EFPD</b>						
Entire Voltage Range	1089	0.66	0.020	0.017	3.0%	2.5%
V <sub>BOC</sub> < .75 Volts	751	0.50	0.040	0.034	8.0%	6.7%
≥ .75 Volts	338	1.01	-0.010	-0.008	-1.0%	-0.8%
<b>Cycle 9 (1991 - 1993) - 492.75 EFPD</b>						
Entire Voltage Range	1125	0.57	0.090	0.067	15.8%	11.7%
V <sub>BOC</sub> < .75 Volts	918	0.47	0.090	0.067	19.1%	14.2%
≥ .75 Volts	207	1.02	0.090	0.067	8.8%	6.5%
<b>Cycle 8 (1989 - 1991) - 390.82 EFPD</b>						
Entire Voltage Range	952	0.95	0.180	0.168	18.9%	17.7%
V <sub>BOC</sub> < .75 Volts	366	0.58	0.160	0.150	27.6%	25.8%
≥ .75 Volts	586	1.18	0.190	0.178	16.1%	15.0%
<b>Cycle 7 (1987 - 1989) - 438.3 EFPD</b>						
Entire Voltage Range	918	0.66	0.290	0.242	43.9%	36.6%
V <sub>BOC</sub> < .75 Volts	622	0.49	0.270	0.225	55.1%	45.9%
≥ .75 Volts	296	1.01	0.340	0.283	33.7%	28.1%

**Table 3-8**  
**Beaver Valley Unit-1 October 1997**  
**Voltage Growth Statistics - Composite of All Steam Generator Data**  
**(Based on EOC-11 Bobbin Voltages Multiplied by 0.874 for Calibration Adjustment)**

Bobbin Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Average Percentage Growth	
			Entire Cycle	Per EFPY	Entire Cycle	Per EFPY
<b>Cycle 12 (1996 - 1997) - 415.4 EFPD</b>						
Entire Voltage Range	2910	0.60	-0.025	-0.022	-4.3%	-3.8%
V <sub>BOC</sub> < .75 Volts	2181	0.46	-0.020	-0.017	-4.4%	-3.8%
≥ .75 Volts	729	1.01	-0.042	-0.037	-4.1%	-3.6%
<b>Cycle 11 (1995 - 1996) - 352.94 EFPD</b>						
Entire Voltage Range	1936	0.60	-0.005	-0.005	-0.8%	-0.9%
V <sub>BOC</sub> < .75 Volts	1434	0.48	0.006	0.007	1.3%	1.4%
≥ .75 Volts	502	0.94	-0.037	-0.038	-4.0%	-4.1%
<b>Cycle 10 (1993 - 1995) - 435.79 EFPD</b>						
Entire Voltage Range	1089	0.66	0.020	0.017	3.0%	2.5%
V <sub>BOC</sub> < .75 Volts	751	0.50	0.040	0.034	8.0%	6.7%
≥ .75 Volts	338	1.01	-0.010	-0.008	-1.0%	-0.8%
<b>Cycle 9 (1991 - 1993) - 492.75 EFPD</b>						
Entire Voltage Range	1125	0.57	0.090	0.067	15.8%	11.7%
V <sub>BOC</sub> < .75 Volts	918	0.47	0.090	0.067	19.1%	14.2%
≥ .75 Volts	207	1.02	0.090	0.067	8.8%	6.5%
<b>Cycle 8 (1989 - 1991) - 390.82 EFPD</b>						
Entire Voltage Range	952	0.95	0.180	0.168	18.9%	17.7%
V <sub>BOC</sub> < .75 Volts	366	0.58	0.160	0.150	27.6%	25.8%
≥ .75 Volts	586	1.18	0.190	0.178	16.1%	15.0%
<b>Cycle 7 (1987 - 1989) - 438.3 EFPD</b>						
Entire Voltage Range	918	0.66	0.290	0.242	43.9%	36.6%
V <sub>BOC</sub> < .75 Volts	622	0.49	0.270	0.225	55.1%	45.9%
≥ .75 Volts	296	1.01	0.340	0.283	33.7%	28.1%

**Table 3-9**  
**Beaver Valley Unit-1 October 1997 Outage**  
**Comparison of Growth Rates for Active and Deplugged Tubes**  
**Average Growth Rate per EFPPY**  
**(Based on EOC-11 Bobbin Voltages Adjusted for Calibration Differences)**

Indication Type	Growths in Tubes Deplugged at EOC-10 versus Tubes Active in Cycle 10		Growths in Tubes Deplugged at EOC-11 versus Tubes Active in Cycle 11
	Cycle 11 Growth (Volts/EFPPY)	Cycle 12 Growth (Volts/EFPPY)	
SG-A, Active Tubes	-0.0486	-0.0042	-0.0035
SG-A, Tubes Deplugged at the beginning of Cycle	0.0071	0.0018	0.1041
SG-A Combined	-0.0402	-0.0035	0.0085
SG-B, Active Tubes	0.0214	-0.0591	-0.0617
SG-B, Tubes Deplugged at the beginning of Cycle	0.1265	-0.0186	-0.0201
SG-B Combined	0.0401	-0.0308	-0.0555
SG-C, Active Tubes	-0.0096	-0.0511	-0.0511
SG-C, Tubes Deplugged at the beginning of Cycle	No deplugged tubes	No deplugged tubes	0.0020
SG-C Combined	-0.0096	-0.0511	-0.0327
All SGs - Active Tubes	-0.0157	-0.0322	-0.0325
All SGs, Tubes Deplugged at the beginning of Cycle	0.0658	-0.0078	0.0228
All SGs Combined	-0.0051	-0.0224	-0.0223

**Table 3-10**  
**Beaver Valley Unit-1 October 1997**  
**Summary of Largest Voltage Growth Rates for BOC-12 to EOC-12**  
**(Based on EOC-11 Bobbin Voltages Multiplied by 0.874 for Calibration Adjustment)**

Steam Generator				Bobbin Voltage			RPC	New
SC	Row	Col	Elevation	EOC	BOC	Growth <sup>#</sup>	Confirmed ?	Indication ?
A	28	60	01H	1.61	0.65	0.96	Y	N
A	31	62	01H	1.51	0.68	0.83	Y	N
C	29	22	01H	1.21	0.76	0.45	Y	N
A	20	11	02H	0.78	0.39	0.39	Y	Y
A	25	78	04H	1.06	0.68	0.38	Y	N
A	18	78	01H	0.97	0.6	0.37	Y	N
B	14	81	02H	1.2	0.84	0.36	Y	Y
A	5	19	02H	0.97	0.63	0.34	Y	Y
A	8	84	03H	0.55	0.23	0.32	N	Y
A	31	68	02H	1.37	1.07	0.3	Y	N
A	6	12	01H	1.68	1.39	0.29	Y	N
B	15	26	02H	0.76	0.47	0.29	Y	N
A	31	42	01H	1.11	0.83	0.28	Y	N
A	21	75	02H	0.44	0.17	0.27	N	Y
A	33	30	01H	1.42	1.15	0.27	Y	N
A	35	35	01H	1.03	0.76	0.27	Y	Y
C	21	22	01H	1.42	1.16	0.26	Y	N
A	26	11	01H	1.48	1.23	0.25	Y	N
C	38	32	01H	0.91	0.66	0.25	N	N
A	6	18	03H	0.74	0.5	0.24	Y	N
A	35	35	02H	1.55	1.31	0.24	Y	N
A	17	14	01H	1.05	0.82	0.23	Y	Y
A	23	23	01H	0.9	0.67	0.23	Y	N
B	8	82	02H	0.69	0.47	0.22	N	Y
C	15	62	02H	0.98	0.76	0.22	Y	N
C	24	28	01H	1.16	0.94	0.22	Y	N
C	32	24	02H	0.73	0.51	0.22	Y	N
C	33	68	01H	1.15	0.93	0.22	Y	N
A	23	47	01H	0.52	0.31	0.21	N	N
A	7	8	01H	1.2	0.99	0.21	Y	N

# Based on EOC-11 voltages adjusted for calibration differences.

**Table 3-11  
Beaver Valley Unit-1 1997 EOC-12 Evaluation for Probability of Prior Cycle Detection  
Composite of All Steam Generator Data**

Voltage Bin	New Indications		EOC-12 Bobbin, Field Call in 1996 Inspection		1996 Inspection Bobbin	POPCD			
	1997 Inspection RPC Confirmed	1997 Inspection RPC Confirmed plus not Inspected	1997 Inspection RPC Confirmed	1997 Inspection RPC Confirmed plus not Inspected	1996 Inspection Confirmed and Plugged	RPC Confirmed		RPC Confirmed Plus Not Inspected	
						Frac.	Count	Frac.	Count
> 0 - 0.2	5	61	0	78	0	0.0	0 / 5	0.561	78 / 139
0.2 - 0.4	35	266	35	600	1	0.507	36 / 71	0.693	601 / 867
0.4 - 0.6	39	149	59	646	0	0.602	59 / 98	0.813	646 / 795
0.6 - 0.8	26	55	92	392	0	0.780	92 / 118	0.877	392 / 447
0.8 - 1.0	11	16	138	217	0	0.926	138 / 149	0.931	217 / 233
1.0 - 1.5	4	4	191	207	0	0.979	191 / 195	0.981	207 / 211
1.5 - 2.0	1	1	29	30	0	0.967	29 / 30	0.968	30 / 31
2.0 - 3.0	2	2	0	0	1	0.333	1 / 3	0.333	1 / 3
3.0 - 4.5	0	0	0	0	1	1.000	1 / 1	1.000	1 / 1
TOTAL	123	554	544	2170	3				
> 1V	7	7	220	237	2				

**Table 3-12  
Beaver Valley Unit-1  
Analysis of RPC Data from 1996 and 1997 Inspections  
Combined Data from All Steam Generators**

Group of Indications	Total 1996 Inspection Bobbin Indication	Total 1997 Inspection Bobbin Indication	Total 1997 Inspection RPC Inspected	Total 1997 Inspection RPC Confirmed	Percent 1997 Inspection RPC Confirmed
<b>Less than or Equal to 1.0 Volt in 1997 Inspection</b>					
1996 Inspection Bobbin Left in Service	2090	2018	411	310	75.4
- 1996 Inspection RPC Confirmed	37	37	12	12	100.0
- 1996 Inspection RPC NDD	31	31	7	1	14.3
- 1996 Inspection RPC Not Inspected	1950	1950	392	297	75.8
- No 1997 Inspection Bobbin *	72	-	-	-	-
New 1997 Inspection Indication	-	611	180	114	63.3
Sum of All 1997 Inspection Indication	2090	2629	589	424	72.0
<b>Greater than 1.0 Volt in 1997 Inspection</b>					
1996 Inspection Bobbin Left in Service	274	268	249	234	94.0
- 1996 Inspection RPC Confirmed	10	10	10	9	90.0
- 1996 Inspection RPC NDD	4	4	4	2	50.0
- 1996 Inspection RPC Not Inspected	254	254	235	223	94.9
- No 1997 Inspection Bobbin *	6	-	-	-	-
New 1997 Inspection Indication	-	13	13	9	69.2
Sum of All 1997 Inspection Indication	274	281	261	243	93.1
<b>All Voltages in 1997 Inspection</b>					
1996 Inspection Bobbin Left in Service	2364	2286	657	544	82.8
- 1996 Inspection RPC Confirmed	47	47	22	21	95.5
- 1996 Inspection RPC NDD	35	35	11	3	27.3
- 1996 Inspection RPC Not Inspected	2204	2204	624	520	83.3
- No 1997 Inspection Bobbin *	78	-	-	-	-
New 1997 Inspection Indication	-	624	193	123	63.7
Sum of All 1997 Inspection Indication	2364	2910	850	667	78.5

\* Indications split is based on 1996 Inspection bobbin voltage

**Figure 3-1**  
**Beaver Valley Unit-1 October 97 Outage**  
**Bobbin Voltage Distributions at EOC-12 for Tubes in Service During Cycle 12**

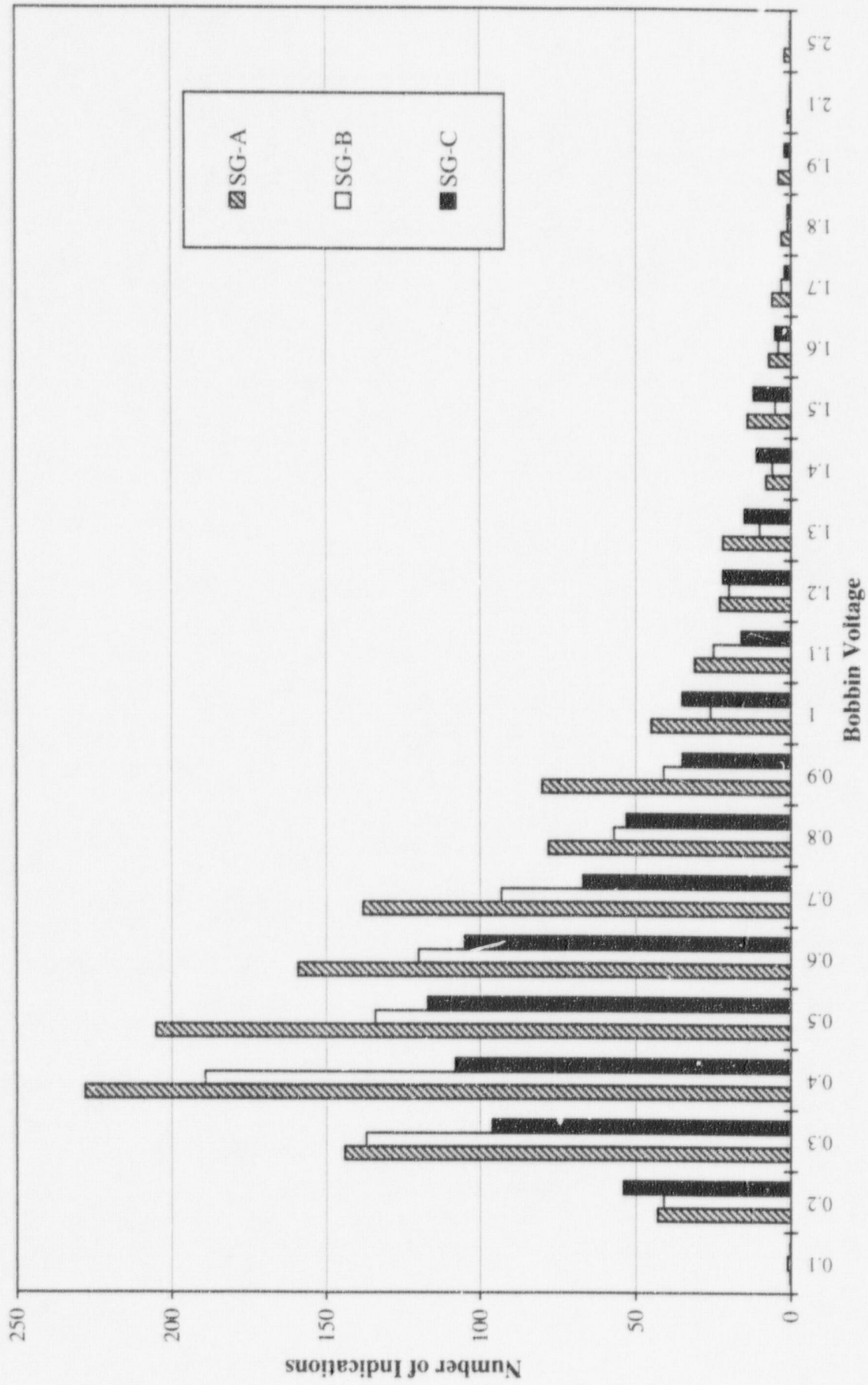


Figure 3-2  
 Beaver Valley Unit-1 October 97 Outage  
 Bobbin Voltage Distribution for Tubes Plugged After Cycle 12 Service

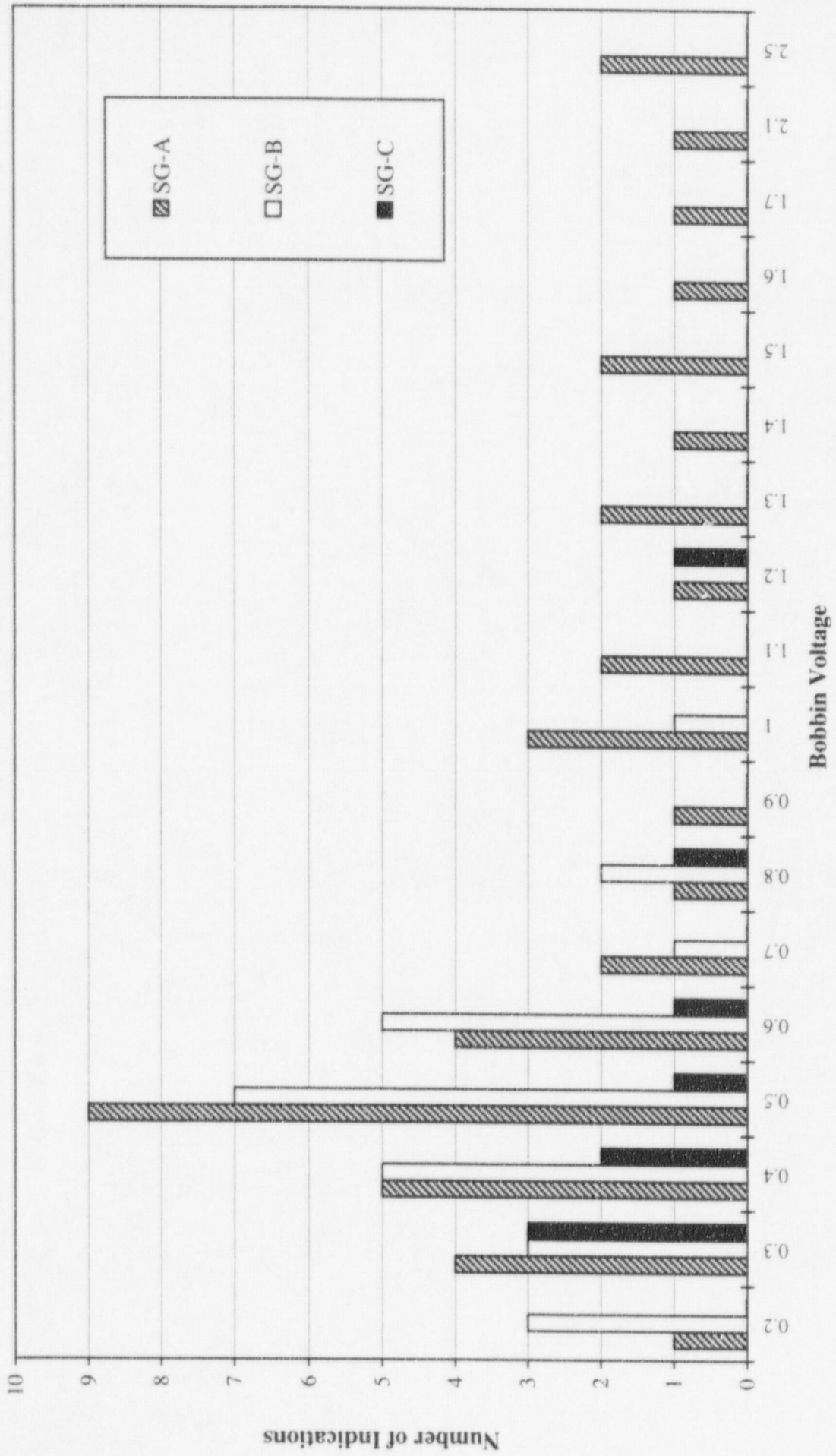


Figure 3-3  
 Beaver Valley Unit-1 October 97 Outage  
 Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 13

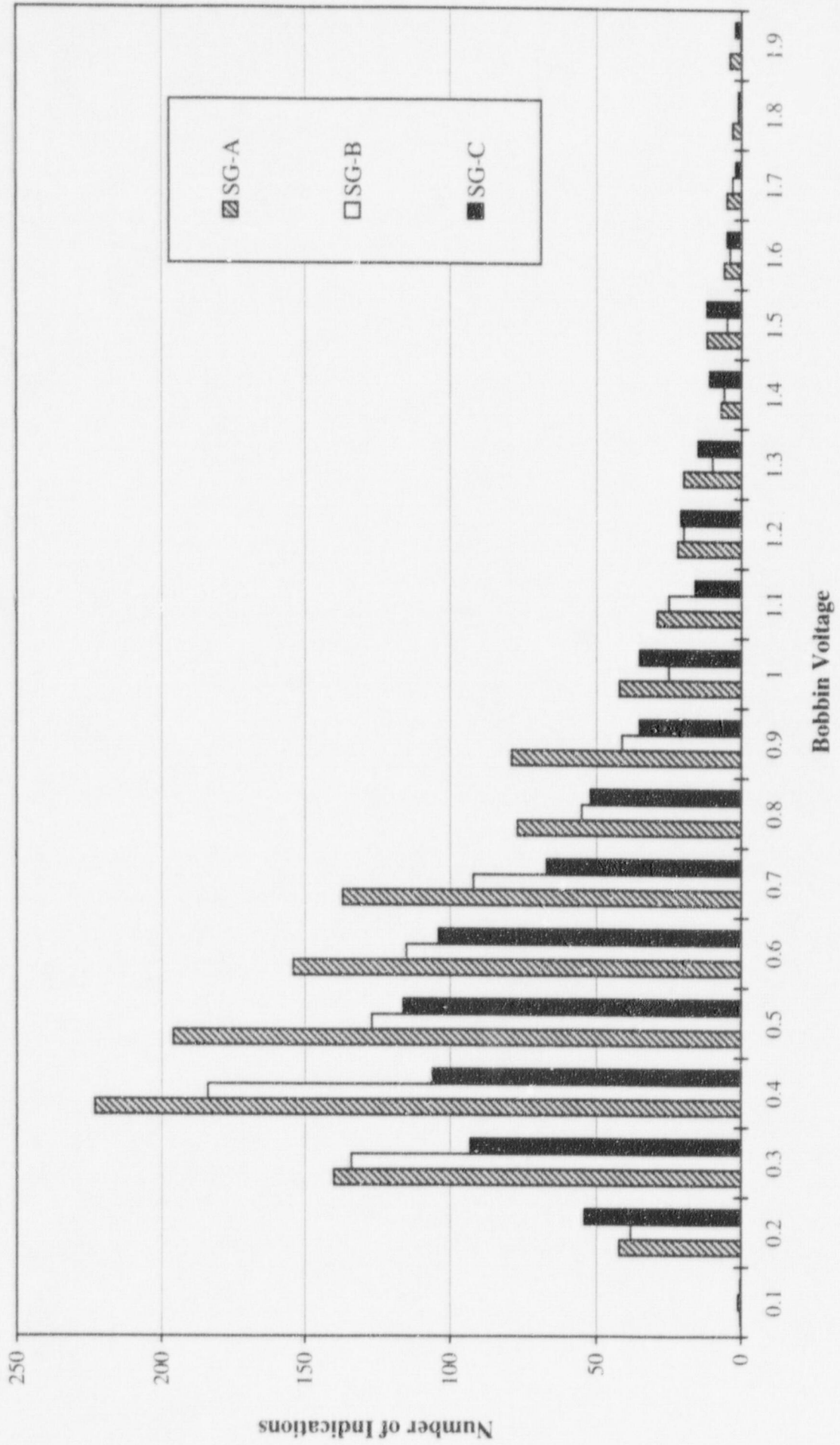


Figure 3-4  
 Beaver Valley Unit-1 - October 1997  
 ODSCC Axial Distributions for Tubes in Service During Cycle 12

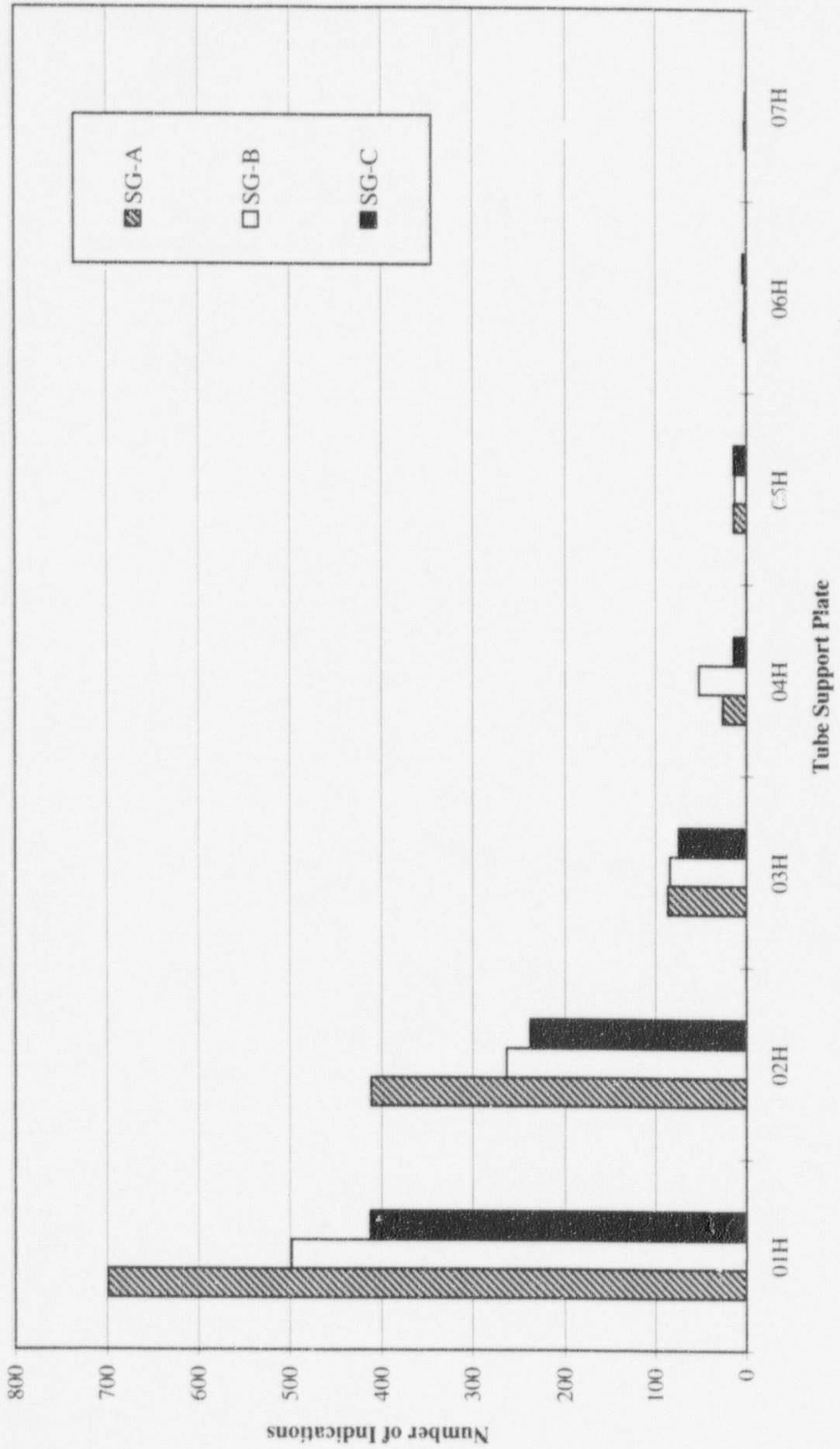


Figure 3-5  
 Beaver Valley Unit-1 Cycle 12 ( May 1996 to October 1997 )  
 Cumulative Probability Distributions for Voltage Growth on an EPY Basis

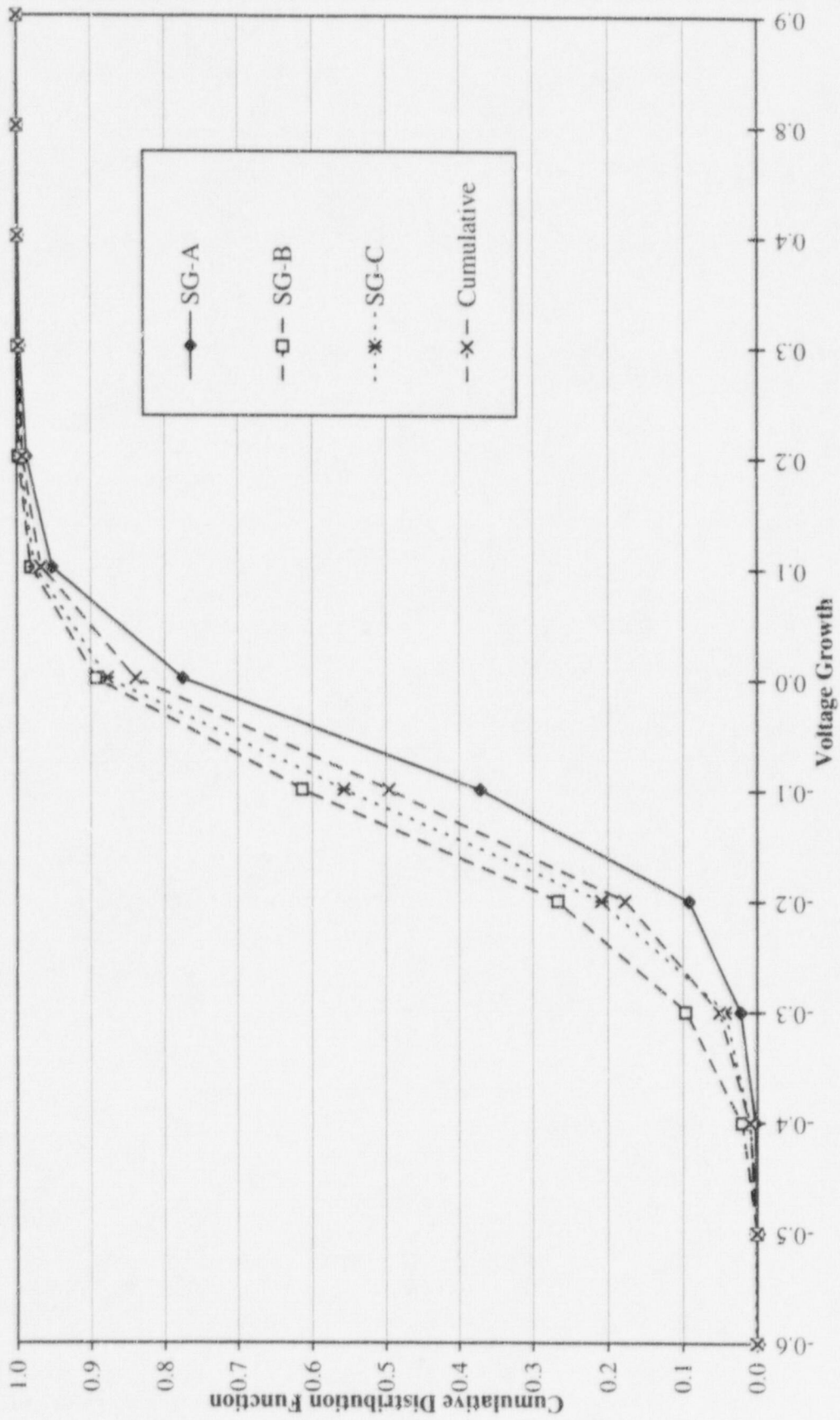


Figure 3-6  
 Beaver Valley Unit-1 - October 1997  
 Bobbin Signal Growth History - Cumulative Probability Distributions on an EPFY Basis  
 Composite of All Steam Generators

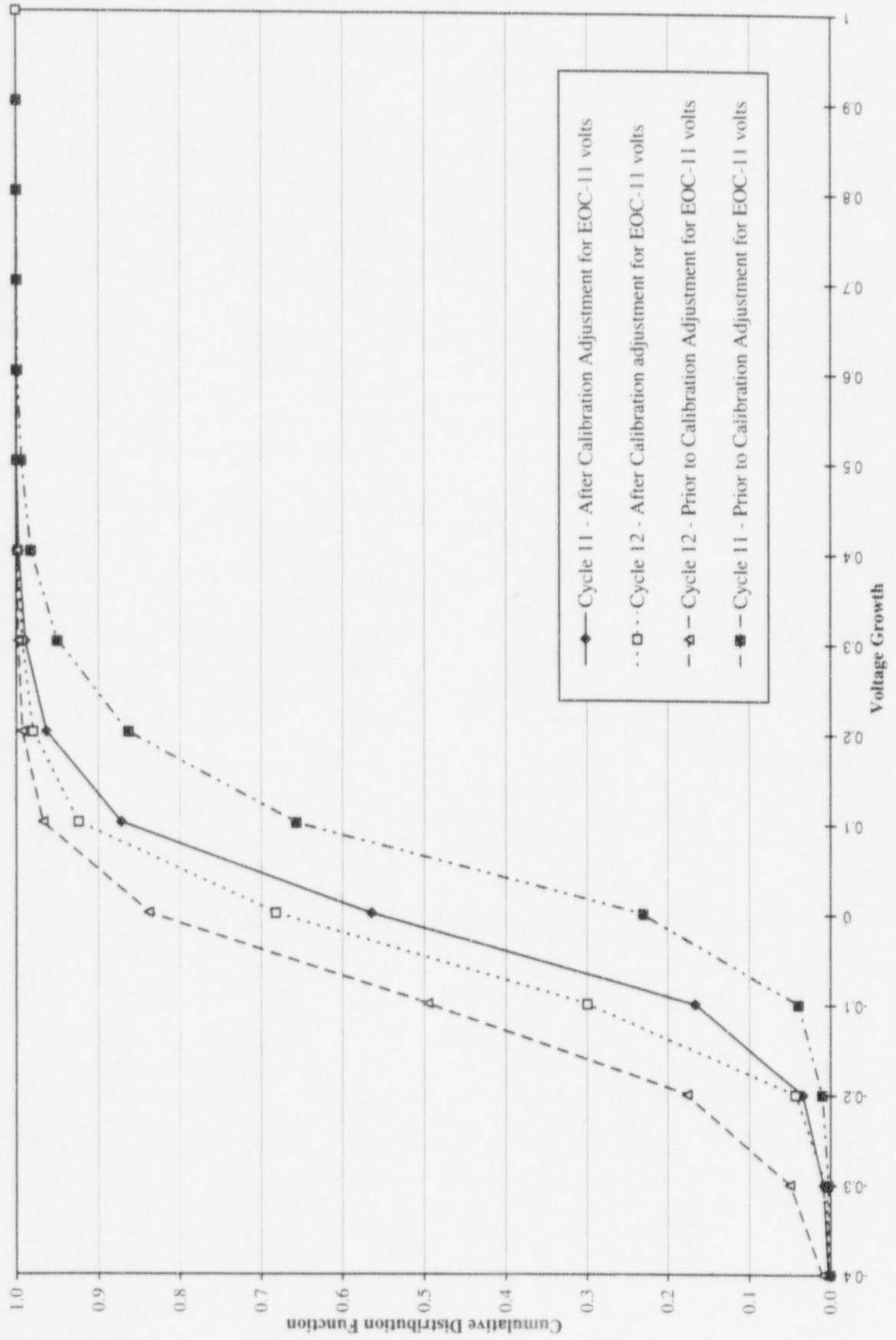


Figure 3-7  
Beaver Valley Unit -1 October 1997 Outage  
Voltage Growth During Cycle 12 vs BOC-12 voltage  
(Growth Data Based on EOC-11 Voltages Adjusted for Calibration Differences)

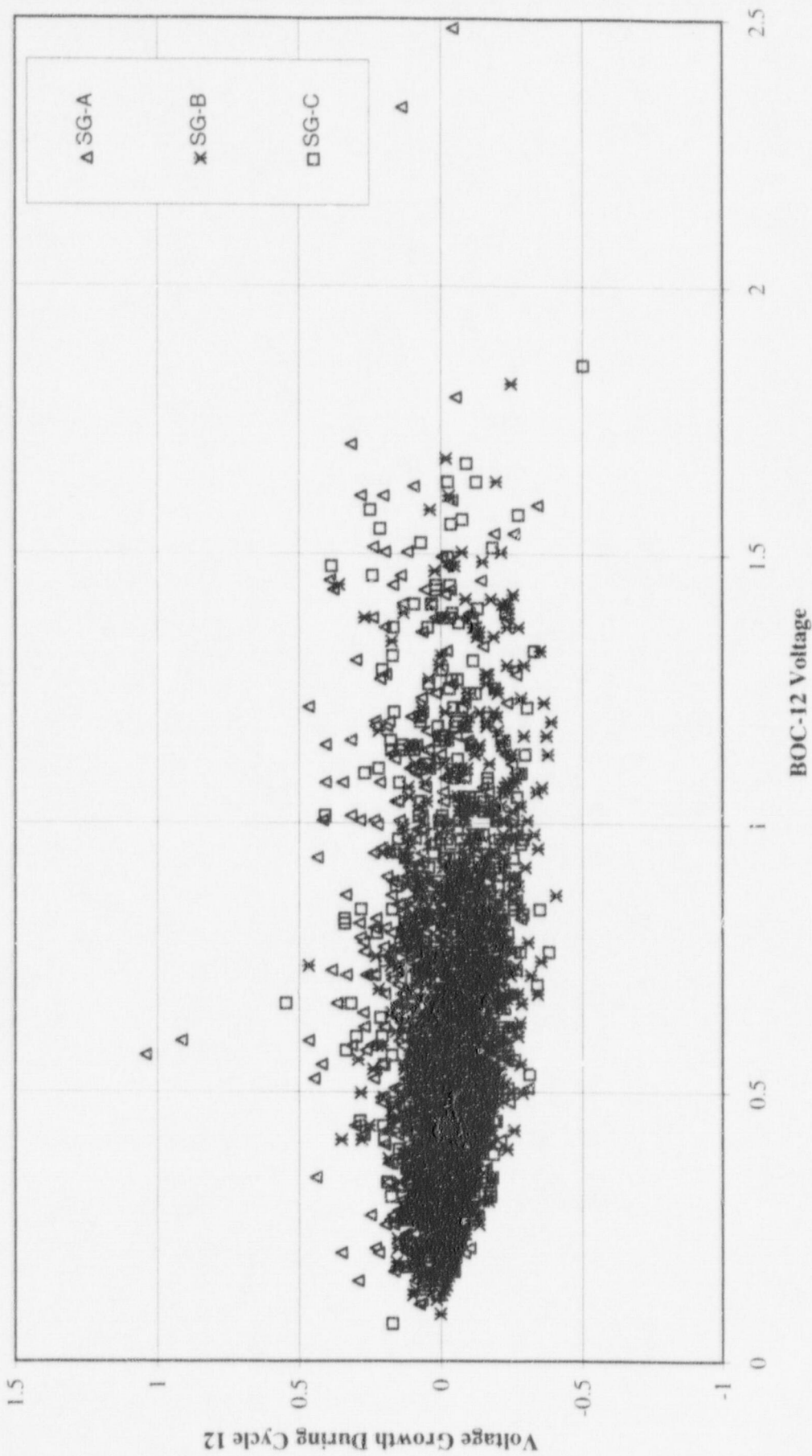
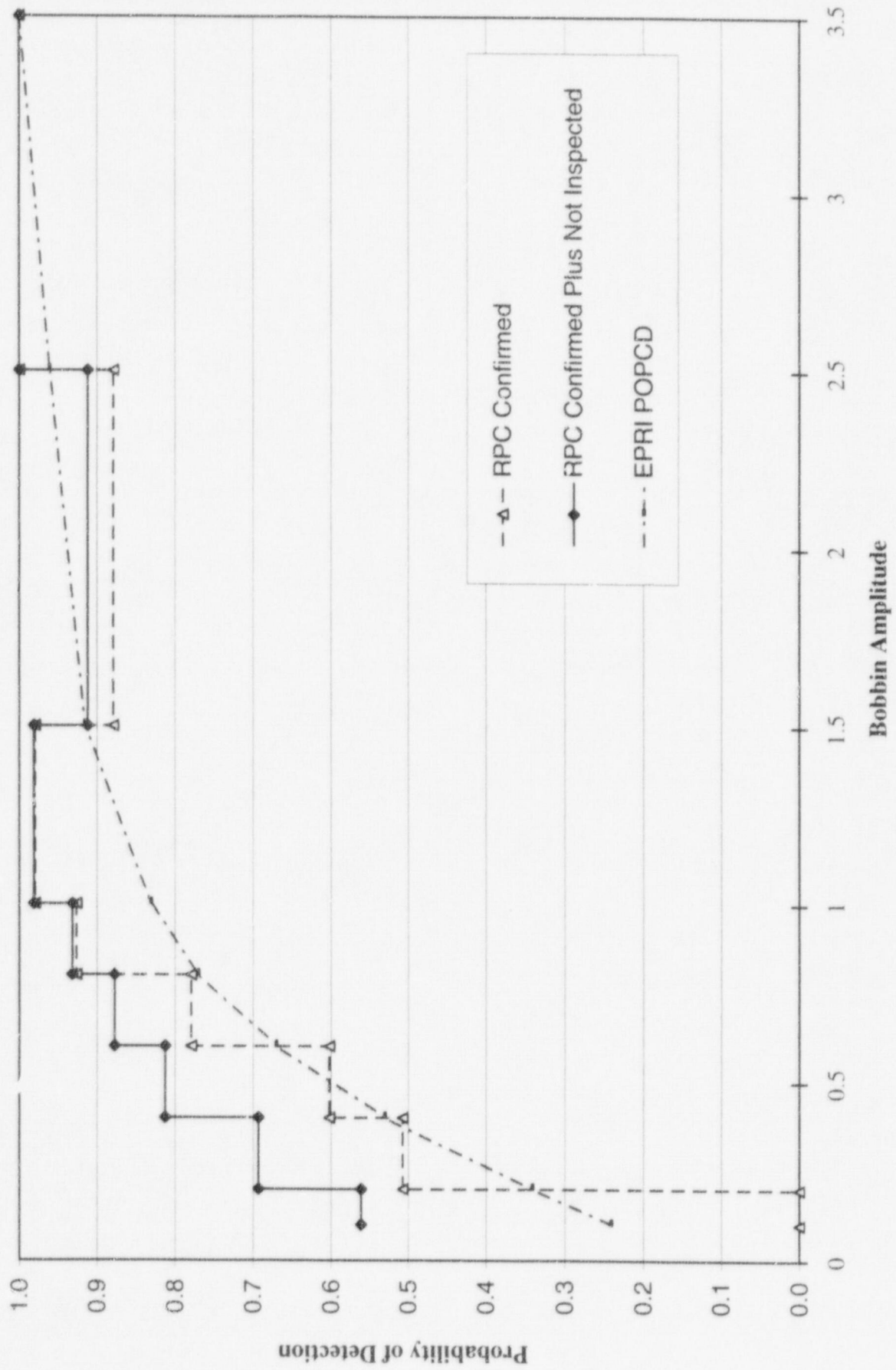


Figure 3-8  
 Beaver Valley Unit-1  
 1997 EOC-12 Evaluation for POPCD at EOC-11



#### 4.0 Database Applied for Leak and Burst Correlations

The leak and burst correlations utilized in the analyses presented in this report are based on an updated ARC database. The database protocol submitted to the NRC in the Fall of 1997 indicates that the database should be updated if "...the inclusion of new data results in a non-conservative shift in the correlation predictions..." Inclusion of recent pulled tube data from Plans A-1 and A-2 makes the leak and burst correlations less conservative. So, as an interim update of the database, Plants A-1 and A-2 data were added to the Reference 8-4 database and leak and burst correlations were reevaluated. The parameters of the updated leak and burst correlations are presented in Reference 8-8. As required by the NRC, Model Boiler specimen 542-4 and Plant J-1 pulled tube R8C74, TSP1 are included in the database applied.

A leak rate correlation can now be applied to 7/8" tubes because NRC recently stated (Reference 8-10) that the p-value for the slope of the leak rate correlation determined on a one-sided basis (as opposed to a two-sided basis test used until now) can be used to test the significance of the correlation. Reference 8-8 presents the results of a regression analysis for the voltage dependent leak rate correlation using the updated leak rate database for 7/8" tubes mentioned above. It is shown that the one-sided p-value for the slope parameter in the voltage dependent leak rate correlation is 3.8% which is below the 5% threshold for an acceptable correlation specified in the Generic Letter 95-05. Thus, the leak rate database for 7/8" tubes now satisfies the statistical test for a correlation.

The following leak rate correlation is developed in Reference 8-8 for 7/8" tubes based on an updated ARC database that includes the recent Plants A-1 and A-2 data.

$$\text{Leak Rate (l/hr)} = 10^{\left(-0.5036 + 0.9709 \times \log_{10}(\text{volts})\right)}$$

The above leak rate correlation was used to perform EOC-13 SLB leak rate projections for all three SGs .

## 5.0 SLB Analysis Methods

Monte Carlo analyses are used to calculate the SLB leak rates and tube burst probabilities for both actual EOC-12 and projected EOC-13 voltage distributions. The Monte Carlo analysis accounts for parameter uncertainty. The analysis methodology is described in the Westinghouse generic methods report of Reference 8-3, and the same methodology was applied to leak and burst analyses performed during the EOC-11 outage.

In general, the methodology involves application of correlations for burst pressure, probability of leakage 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. Uncertainties associated with burst pressure, leak rate probability and leak rate correlations are explicitly included by sampling distributions for the correlation parameters through a Monte Carlo sampling process. NDE uncertainties are also similarly included. The voltage distributions used in the leak and burst projections 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 distribution 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. The method of treating fractional indications is discussed in Section 3.6 of Reference 8-3. Fractional indications in the EOC voltage bins are retained, and the tail of the distribution is integrated to define discrete values corresponding to the last 1/3<sup>rd</sup> and 2/3<sup>rd</sup> of an indication.

## 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-13 voltage distributions. Also, EOC-12 voltage projections performed during the last outage based on EOC-11 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, SLB leak rates and tube burst probabilities 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.

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

where,

$N_{\text{Tot RTS}}$	=	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,
$N_{\text{repaired}}$	=	Number of $N_i$ which are repaired (plugged) after the last cycle,
$N_{\text{deplugged}}$	=	Number of indications in tubes unplugged after the last cycle and returned to service in accordance with voltage-based repair criteria.

There are no unplugged tubes returned to service at BOC-13; therefore,  $N_{\text{deplugged}} = 0$ .

As noted in Section 3-4, the NRC SER for Beaver Valley-1 allows for consideration of only a fraction of RPC NDD indications from the current inspection in establishing BOC voltage distribution for the next cycle. The fractional value applicable is the largest RPC confirmation rate for prior cycle RPC NDD indications found during the last two outages, but it may not be less than 0.7. RPC confirmation rates for 1995 and 1996 RPC NDD indications are well below 0.7; therefore, only 70% of RPC NDD indication frequency values are considered in establishing the BOC-13 indication distributions shown in Table 6-2. During the Monte Carlo simulations, voltages for bins with 3 or more indications are selected by randomly sampling the voltage bins. For bins with fewer than 3 indications, each indication is considered to be in a separate bin, and the actual indication voltage is utilized in the calculations.

The methodology used in the projection of EOC bobbin voltage frequency predictions is described in Reference 8-3, and it is the same as that used in performing EOC-12 predictions during the last (EOC-11) outage (Reference 8-2). Salient input data used for projecting EOC-12 bobbin voltage frequency are further discussed below.

## **6.2 Probability of Detection (POD)**

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 provides 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 is developed by analyses of 15 inspections in 8 plants and is presented in Table 7-4 of Reference 8-4. The POPCD values applied represent the lower 95% confidence bound, and are reproduced in Table 6-1 as well as 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 distributions from the past two inspections should be utilized for projecting EOC distributions for the next cycle. It is evident from Figure 3-6 that growth rates for Cycle 11 on an EFPY basis are higher than those of Cycle 12; therefore, the Cycle 11 growth rate distribution is used to develop EOC-13 predictions. Cycle 11 growth rates for SG-B are slightly higher than the all SG composite growth distribution and, per the methodology

described in Reference 8-3, SG-specific growth rates are to be used for SG-B while the composite growth rates should be applied for the other two SGs. Although Cycle 11 growth rates shown in Table 3-3 are believed to be overestimated as they are based on unadjusted EOC-11 voltages (see Section 3.2), they were applied to obtain conservative EOC-13 predictions.

Growth distributions used in the Monte Carlo calculations are specified in the form of a histogram, so no interpolation is performed between growth bins. This assures that the largest growth value in the distribution is utilized in the Monte Carlo simulations.

#### **6.4 Cycle Operating Period**

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

Cycle 12	-	BOC-12 to EOC-12	-	415.4 EFPD	or	1.14 EFPY (actual)
Cycle 13	-	BOC-13 to EOC-13	-	500 EFPD	or	1.48 EFPY (projected)

#### **6.5 Projected EOC-13 Voltage Distribution**

Calculations for EOC-13 bobbin voltage projections were performed for all three SGs based on the EOC-12 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-13 are also shown in Table 6-2. Calculations were performed using a constant POD of 0.6 as well as the EPRI POPCD distribution (presented in Table 6-1). The total number of EOC-13 indications predicted with EPRI POPCD for SGs B and C are slightly higher than those based on the POD value of 0.6. The reason for this being that about half of the indication population at EOC-12 is below 0.5 volt and the EPRI POPCD value for such indications is less than 0.6.

The larger growth rates for the last two cycles of operation, which are the Cycle 11 growth rates shown in Table 3-3, were applied. As noted in Section 3.2, growth values shown in Table 3-3 are believed to be overestimated; they were used nevertheless to obtain conservative EOC-13 predictions. The EOC-13 voltage distributions thus projected for all three SGs are summarized on Table 6-3. These results are also shown graphically on Figures 6-2 to 6-4. In general, the results based on a constant POD of 0.6 are slightly more conservative (slightly larger maximum EOC voltage) than those using the voltage-dependent EPRI POPCD.

## 6.6 Comparison of Actual and Projected EOC-12 Voltage Distributions

Table 6-4 and Figure 6-5 provide a comparison of the EOC-12 actual measured bobbin voltage distributions with the corresponding projections performed using the last (EOC-11) inspection bobbin voltage data and presented in Reference 8-2. The EOC-12 projections shown are based on a constant POD of 0.6. As predicted in Reference 8-2, SG-A has the largest number of indications; however, while SG-B was predicted to have the largest indication, SG-A had the largest actual measured bobbin voltage. The actual peak voltages measured are 0.4 to 1.9 volts below their projected values, with the voltage difference being the highest for SG-B (1.9 volts). A comparison of the actual and projected voltage distributions in Figure 6-5 show that the indication population above 0.6 volt is substantially overestimated in the projections based on a constant POD of 0.6. This POD value is conservative for voltages above about 0.5 volt but non-conservative below 0.5 volt as seen in Figure 6-1. As seen in the results for SG-B in Figure 6-5, the projections based on POPCD show better agreement with the actual voltages, while remaining a conservative projection, over the entire voltage range than found for  $POD=0.6$ .

**Table 6-1**  
**EPRI POPCD Distribution**  
**Based on Data from 15 Inspections in 8 Plants**

Voltage Bin	EPRI POPCD <sup>#</sup>
0.1	0.24
0.2	0.34
0.3	0.44
0.4	0.53
0.5	0.62
0.6	0.67
0.7	0.73
0.8	0.77
0.9	0.81
1	0.83
1.2	0.88
1.4	0.91
1.6	0.92
1.8	0.93
2	0.94
3	0.98
3.5	1.0

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

**Table 6-2**  
**Beaver Valley Unit-1 October 1997**  
**EOC-12 Bobbin and Assumed BOC-13 Bobbin Distributions in**  
**SLB Leak Rate and Tube Burst Analyses**

Voltage Bin	Steam Generator A				Steam Generator B				Steam Generator C			
	EOC - 12		BOC - 13*		EOC - 12		BOC - 13*		EOC - 12		BOC - 13*	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POP/CD	Field Bobbin Indications	Indications Repaired	POD 0.6	POP/CD	Field Bobbin Indications	Indications Repaired	POD 0.6	POP/CD
0.1	0	0	0.00	0.00	1	0	1.67	4.17	0	0	0.00	0.00
0.2	43	1	69.17	122.82	41	3	63.33	114.06	54	0	85.00	150.00
0.3	144	4	232.50	318.50	137	3	224.83	307.68	96	3	153.30	210.03
0.4	228	5	367.30	416.43	189	5	305.00	345.94	108	2	173.50	196.68
0.5	205	9	327.17	316.32	134	7	212.83	205.74	117	1	188.50	182.39
0.6	159	4	255.50	228.39	120	5	194.00	173.21	105	1	170.00	152.13
0.7	138	2	224.50	184.16	93	1	152.00	124.75	67	0	110.17	90.55
0.8	78	1	125.50	97.57	57	2	91.50	70.86	53	1	85.83	66.66
0.9	80	1	127.83	94.43	41	0	66.33	49.14	35	0	57.83	42.84
1	45	3	70.00	49.77	26	1	41.83	29.96	35	0	57.83	41.81
1.1	31	2	46.97	32.45	25	0	40.67	28.54	16	0	26.67	18.71
1.2	23	1	36.83	24.80	20	0	32.33	22.05	22	1	35.67	24.00
1.3	22	2	32.97	21.54	10	0	16.67	11.17	15	0	25.00	16.76
1.4	8	1	12.33	7.79	6	0	9.50	6.26	11	0	18.33	12.09
1.5	14	2	21.33	13.30	5	0	8.33	5.46	12	0	20.00	13.11
1.6	7	1	10.17	6.28	4	0	6.17	4.02	5	0	8.33	5.43
1.7	6	1	9.00	5.49	3	0	5.00	3.24	2	0	3.33	2.16
1.8	3	0	5.00	3.23	1	0	1.67	1.08	1	0	1.67	1.08
1.9	4	0	6.67	4.28	0	0	0	0	2	0	3.33	2.14
2.1	1	1	0.67	0.06	0	0	0	0	0	0	0	0
2.5	2	2	1.33	0.08	0	0	0	0	0	0	0	0
Total	1241	43	1982.73	1947.70	913	27	1473.67	1507.34	756	9	1224.30	1228.57
> 1V	121	13	183.27	119.30	74	0	120.33	81.83	86	1	142.33	95.49
> 2V	3	3	2.00	0.14	0	0	0	0	0	0	0	0

\* Only 70% of RPC NDD indications included.

**Table 6-3**  
**Beaver Valley Unit-1 October 1997**  
**Predicted Voltage Distributions for EOC-13**

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C	
	Projected Number of Indications at EOC - 13					
	POD 0.6	EPRI POPCD	POD 0.6	EPRI POPCD	POD 0.6	EPRI POPCD
0.1	0.77	1.37	0.62	1.25	0.95	1.68
0.2	18.86	31.37	10.41	17.79	20.21	34.30
0.3	73.36	105.72	44.40	66.51	57.49	87.13
0.4	156.80	200.82	102.58	137.30	99.43	133.24
0.5	230.80	268.40	157.64	193.26	134.16	160.94
0.6	264.54	282.76	188.34	214.45	152.64	165.47
0.7	257.72	255.17	193.71	204.50	149.46	148.73
0.8	226.96	210.02	175.98	172.93	130.99	121.88
0.9	186.38	162.98	146.72	135.72	107.78	94.63
1.0	146.69	121.98	116.77	102.76	85.71	71.43
1.1	111.46	88.67	90.08	75.72	67.14	53.35
1.2	82.57	63.10	67.96	54.58	52.43	39.94
1.3	60.45	44.51	50.65	39.00	41.27	30.27
1.4	44.33	31.57	37.57	28.06	32.71	23.27
1.5	32.75	22.66	27.56	20.11	25.76	17.92
1.6	24.36	16.44	19.83	14.14	19.91	13.58
1.7	18.19	11.99	14.06	9.82	14.88	10.04
1.8	13.53	8.75	9.84	6.76	10.70	7.15
1.9	9.92	6.34	6.77	4.58	7.41	4.93
2.0	7.13	4.50	4.55	3.05	4.97	3.28
2.1	5.00	3.12	2.97	1.98	3.24	2.13
2.2	3.41	2.08	1.89	1.25	2.05	1.35
2.3	2.27	1.35	1.17	0.77	1.27	0.83
2.4	1.49	0.84	0.60	0.05	0.76	0.14
2.5	0.98	0.21	0.00	0.70	0.00	0.70
2.6	0.65	0.00	0.70	0.00	0.70	0.00
2.7	0.36	0.70	0.30	0.30	0.00	0.30
2.8	0.00	0.30	0.00	0.00	0.30	0.00
2.9	0.70	0.00	0.00	0.00	0.00	0.00
3.1	0.30	0.00	0.00	0.00	0.00	0.00
TOTAL	1982.73	1947.72	1473.67	1507.34	1224.32	1228.61
> 1 V	419.85	307.13	336.50	260.87	285.50	209.18
> 2 V	15.16	8.60	7.63	5.05	8.32	5.45

**Table 6-4**  
**Beaver Valley Unit-1 October 1997**  
**Comparison of Predicted and Actual EOC-12 Voltage Distributions**

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C	
	Prediction	Actual	Prediction	Actual	Prediction	Actual
	POD = 0.6		POD = 0.6		POD = 0.6	
0.1	0.08	0	0.16	1	0.07	0
0.2	4.74	43	6.68	41	3.62	54
0.3	38.73	144	22.88	137	23.63	96
0.4	96.80	228	50.63	189	53.37	108
0.5	149.47	205	86.03	134	77.51	117
0.6	181.66	159	114.88	120	96.28	105
0.7	188.64	138	131.61	93	104.88	67
0.8	176.45	78	135.82	57	101.71	53
0.9	156.36	80	129.58	41	91.26	35
1.0	132.49	45	116.75	26	77.29	35
1.1	106.03	31	100.34	25	62.32	16
1.2	80.22	23	82.66	20	48.36	22
1.3	58.13	22	65.81	10	36.79	15
1.4	41.12	8	51.07	6	27.87	11
1.5	29.06	14	38.91	5	21.19	12
1.6	20.92	7	29.26	4	16.25	5
1.7	15.35	6	21.70	3	12.45	2
1.8	11.38	3	15.86	1	9.43	1
1.9	8.35	4	11.41	0	6.96	2
2.0	5.96	0	7.99	0	4.96	0
2.1	4.13	1	5.48	0	3	0
2.2	2.77	0	3.66	0	2	0
2.3	1.79	0	2.37	0	1.43	0
2.4	1.14	0	1.49	0	0.88	0
2.5	0.71	2	0.91	0	0.21	0
2.6	0.04	0	0.54	0	0.70	0
2.7	0.70	0	0.32	0	0.00	0
2.8	0.00	0	0.05	0	0.30	0
2.9	0.30	0	0.00	0	0	0
3.1	0	0	0.70	0	0	0
3.7	0	0	0.30	0	0	0
TOTAL	1513.50	1241	1235.83	913	885.33	756
> 1 V	388.10	121	440.81	74	255.73	86
> 2 V	11.58	3	15.81	0	9.15	0

**Figure 6-1**  
**EPRI POPCD Distribution Based on 15 Inspections in 8 Plants**  
**Lower 95% Confidence Bound**

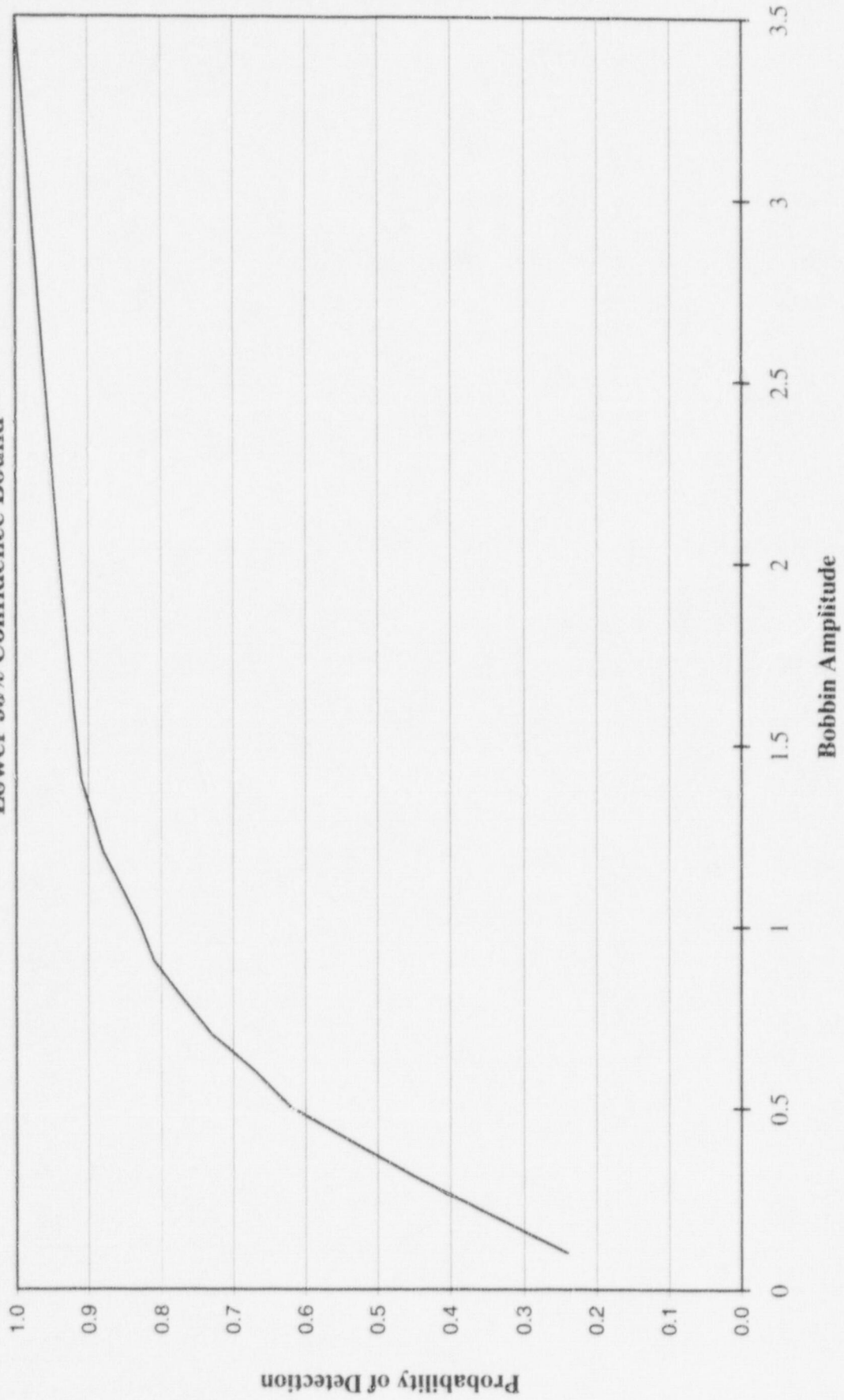


Figure 6-2  
 Beaver Valley Unit-1 -- SG-A  
 Predicted Bobbin Voltage Distribution for Cycle 13

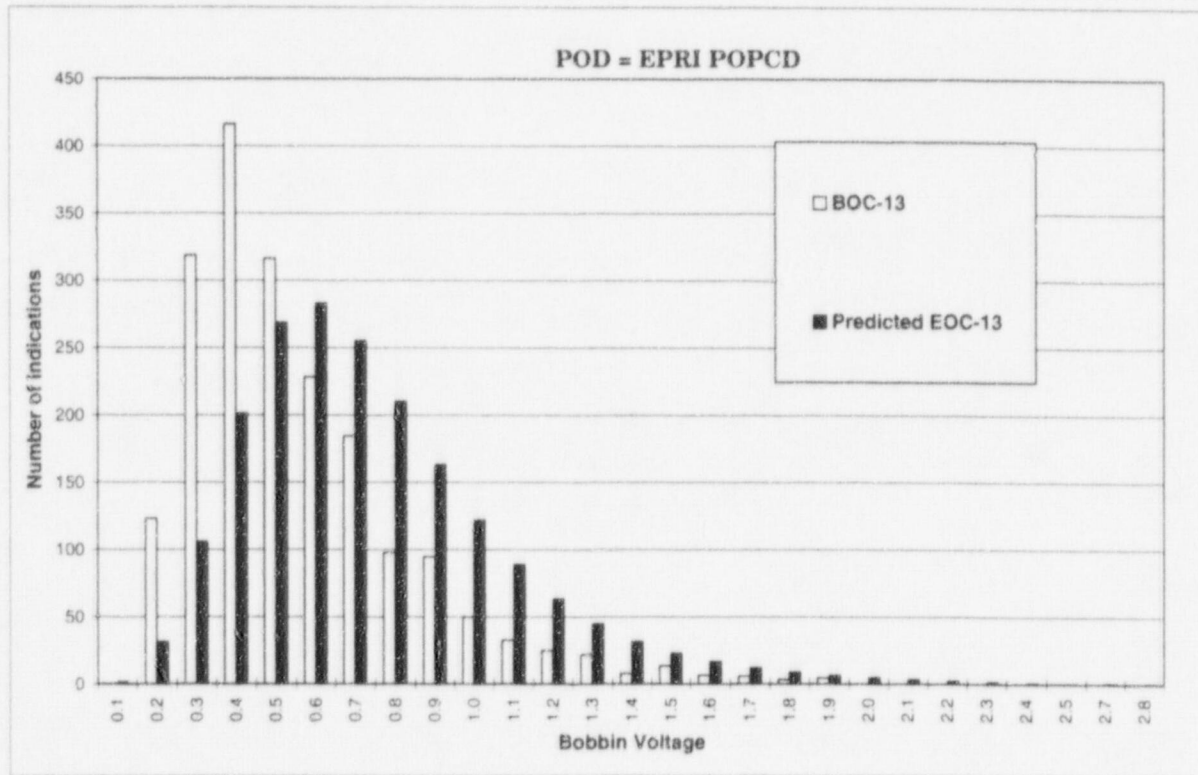
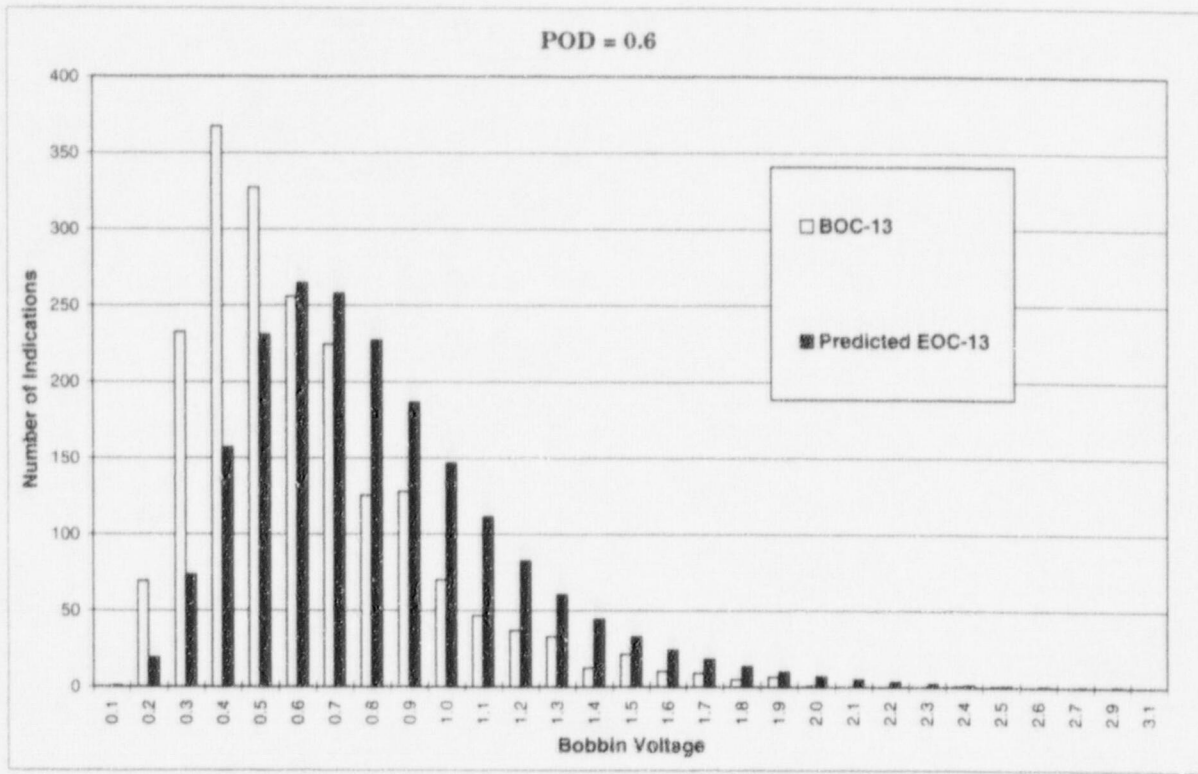


Figure 6-3  
 Beaver Valley Unit-1 -- SG-B  
 Predicted Bobbin Voltage Distribution for Cycle 13

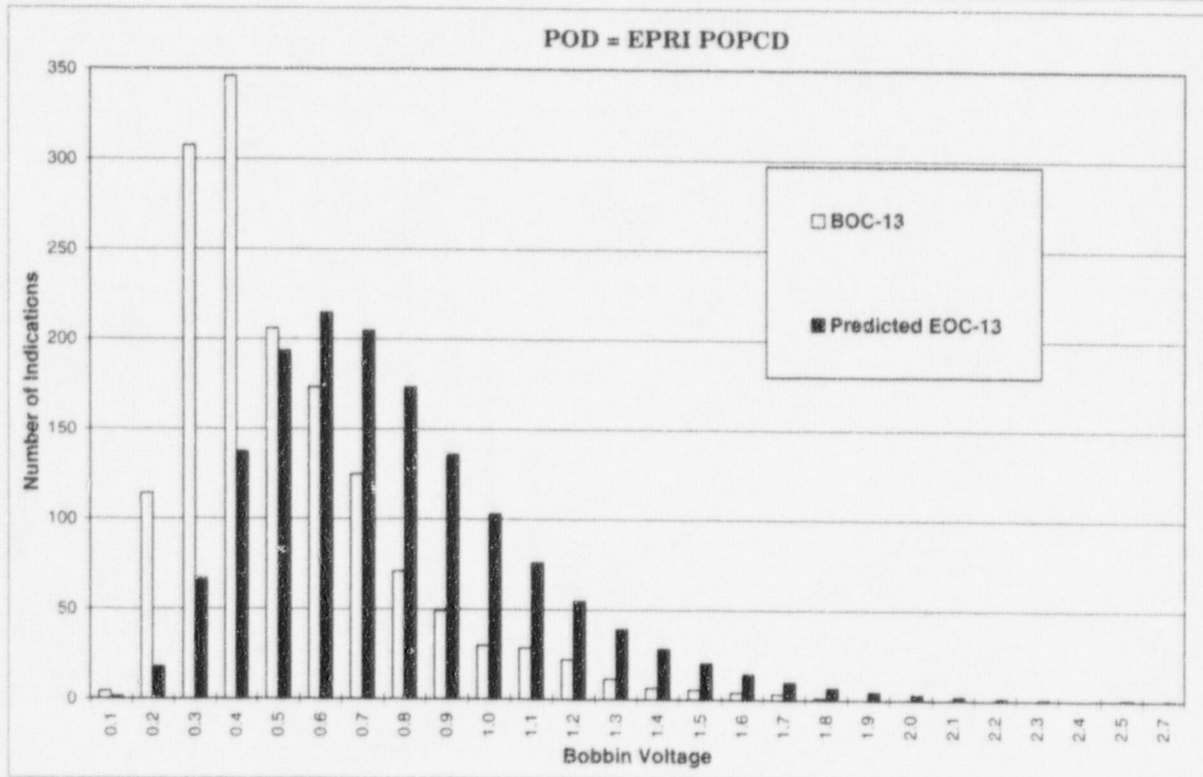
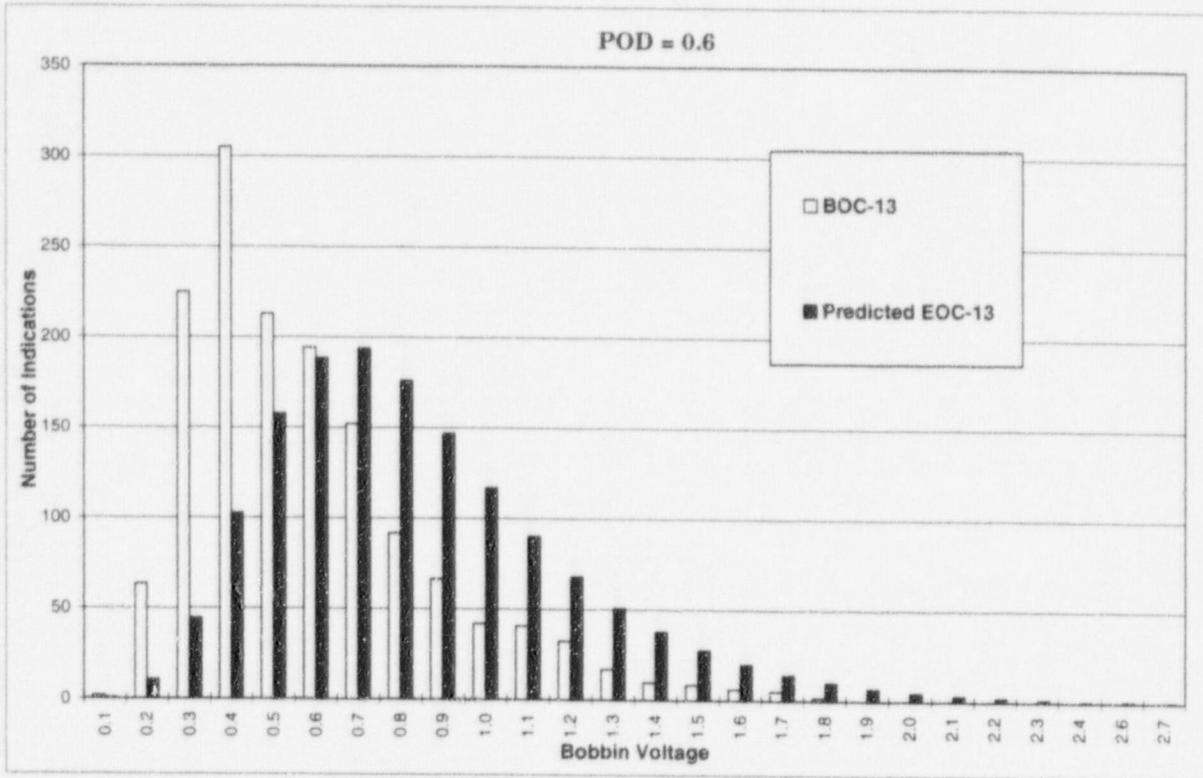


Figure 6-4  
 Beaver Valley Unit-1 -- SG-C  
 Predicted Bobbin Voltage Distribution for Cycle 13

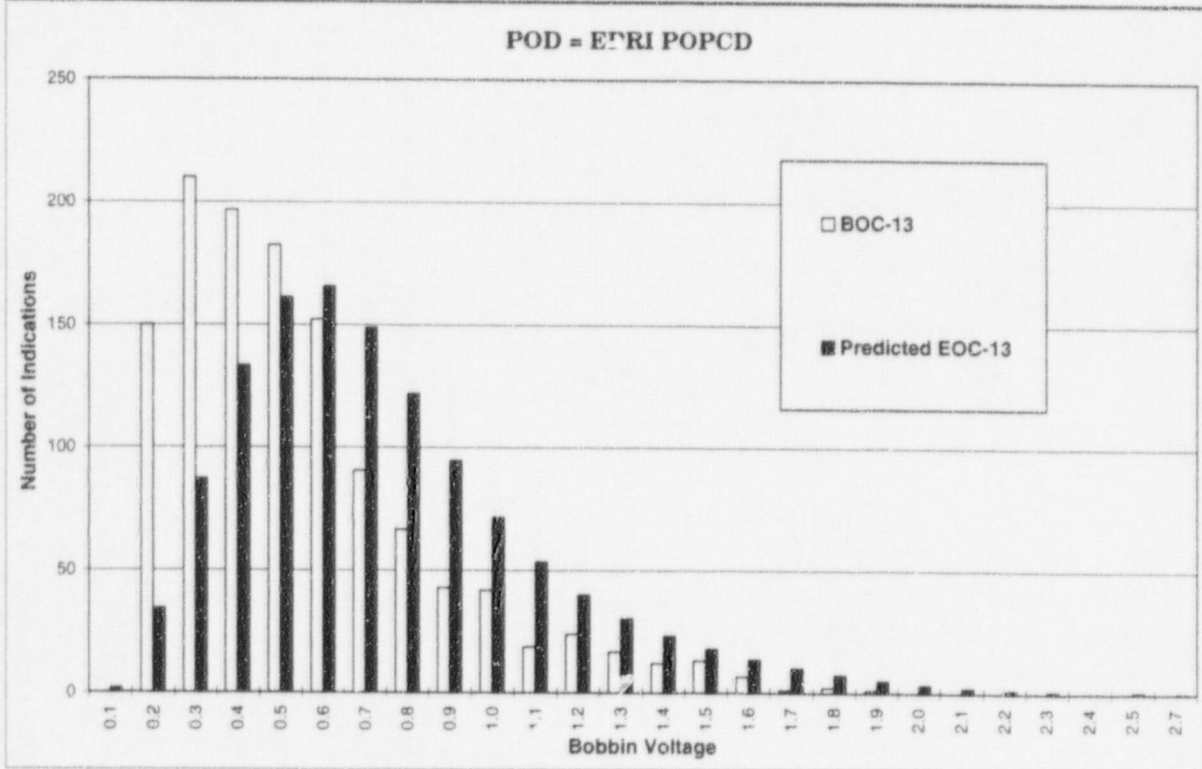
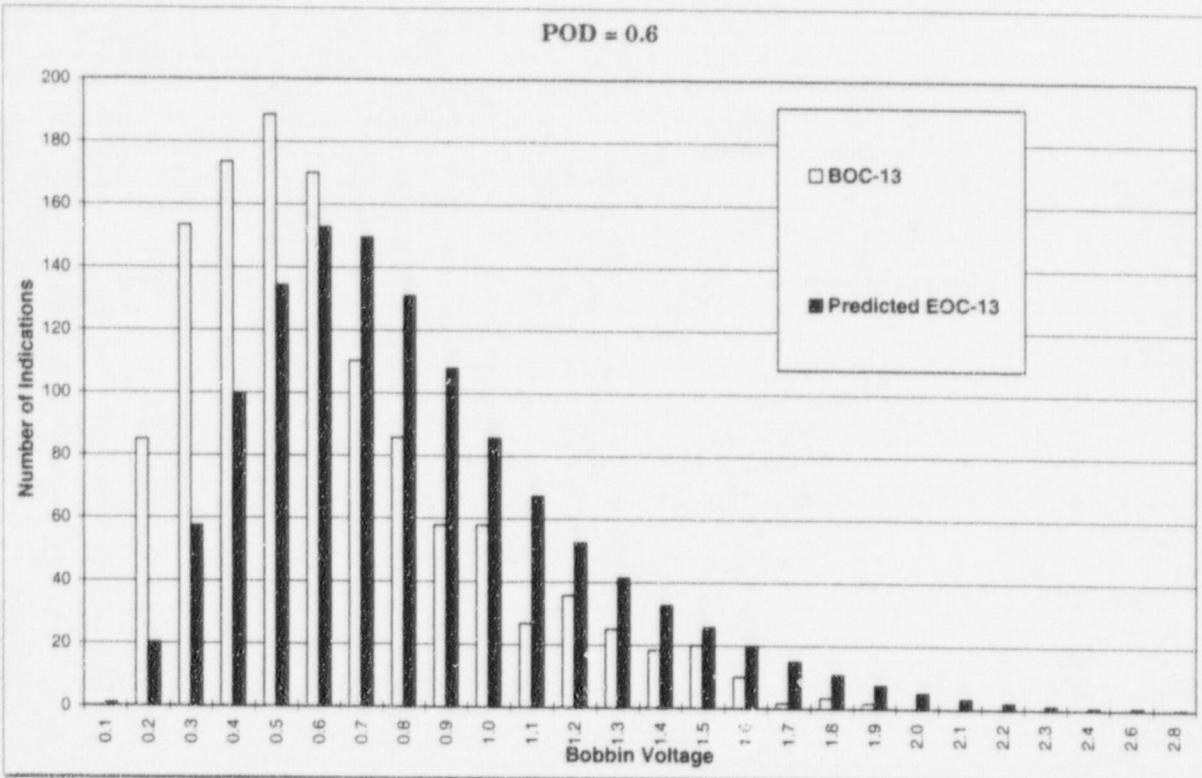
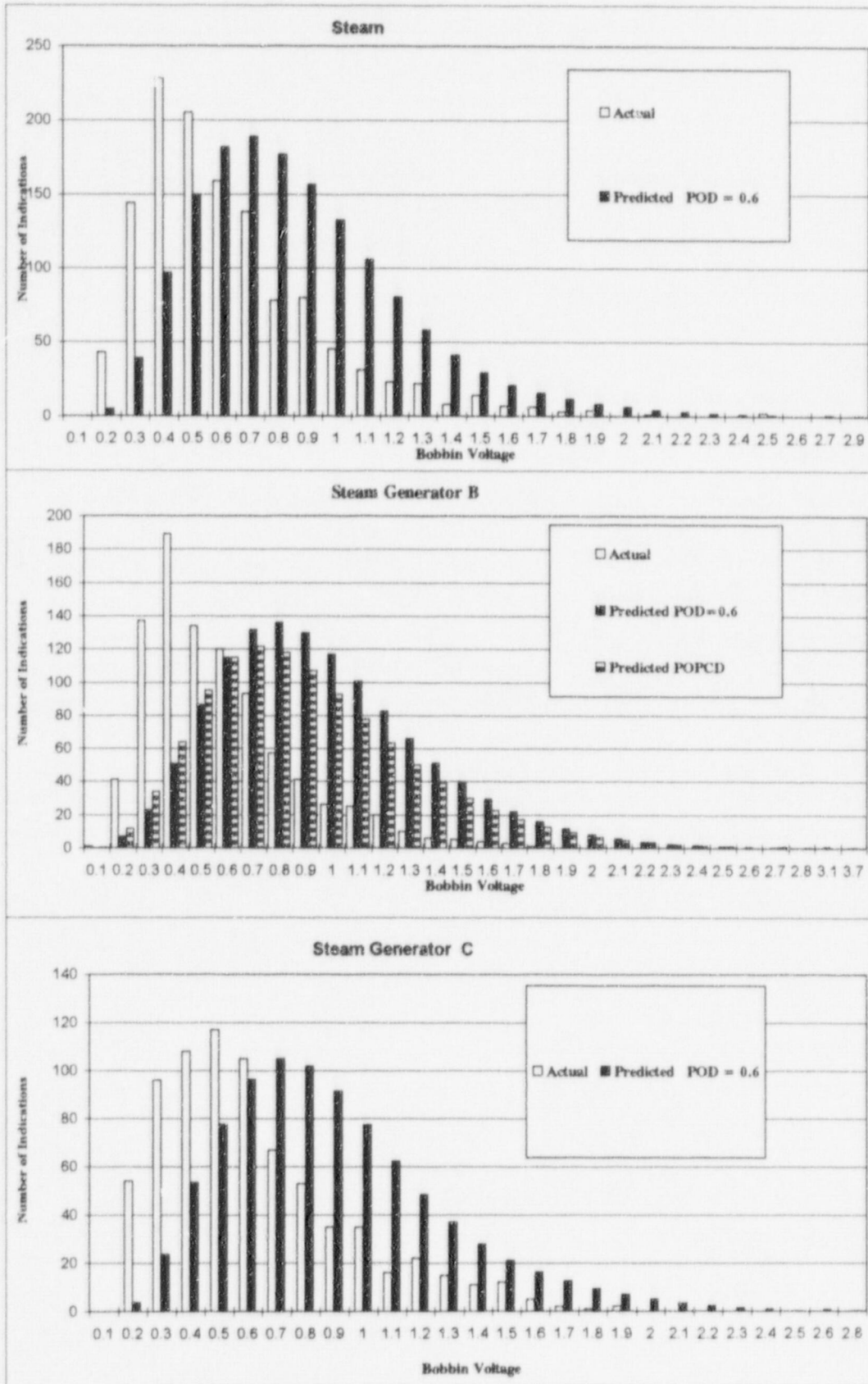


Figure 6-5  
 Beaver Valley Unit-1 October 1997  
 Bobbin Voltage Distributions for Cycle 12



## 7.0 SLB Leak Rate and Tube Burst Probability Analyses

This section presents the results of analyses carried out to predict leak rates and tube burst probabilities for postulated SLB conditions using the actual voltage distributions from the EOC-12 inspection as well as for the projected EOC-13 voltage distributions. The methodology used in these analyses is described in Section 5.0. SG-A with the largest total number of indications as well as indications over 1 volt is expected to yield the limiting SLB leak rate and burst probability for Cycle 13.

### 7.1 Leak Rate and Tube Burst Probability for EOC-12

Analyses to calculate EOC-12 SLB leak rates and tube burst probabilities were performed using the actual bobbin voltage distributions presented in Table 6-2. Results of Monte Carlo calculations are summarized on Table 7-1. A comparison of the EOC-12 actuals in Table 7-1 with the corresponding predictions performed during the EOC-11 inspection, presented in Reference 8-2, indicates the following.

- a) Total number of indications found in the EOC-12 inspection for all three SGs are well below their projection based on  $POD=0.6$ . The peak measured voltage for all SGs are 0.4 to 1.9 volts below their projected values, with the voltage difference being the highest for SG-B.
- b) Leak rate and tube burst probability projections at EOC-12 are conservative compared to the corresponding values calculated using EOC-12 actual measured bobbin measurements for all SGs.
- c) SG-B was predicted to be the limiting steam generator (slightly more conservative than SG-A) at EOC-12 based on the SLB leak rate and tube burst probability projection performed during the EOC-11 outage, but SG-A was found to have the highest leak rate and tube burst probability based on the actual EC bobbin measurements for EOC-12.
- d) Limiting values for SLB leak rate (2.4 gpm, without correlation; 0.3 gpm, with correlation) and tube burst probability ( $9.7 \times 10^{-5}$ ) obtained using the actual measured voltages are well below the allowable SLB leakage limit effective at EOC-12 (8.0 gpm, room temperature) and the NRC reporting guideline of  $10^{-2}$  for the tube burst probability.
- e) Leak rate and burst probability correlations used with the actual voltages are more conservative than those utilized for the projections. An additional calculation for SG-A performed using the same correlations applied for projections show a higher margin for the projection (see Table 7-1).

In summary, actual measured EOC-12 bobbin voltage distributions for all SGs are well below the corresponding projections obtained using the NRC mandated probability of detection of 0.6.

## 7.2 Leak Rate and Tube Burst Probability for EOC-13

Calculations to predict SLB leak rate and tube burst probability for the limiting steam generator in Beaver Valley Unit-1 at the EOC-13 condition were carried out using two values for POD: 1) NRC required constant value of 0.6, 2) voltage dependent EPRI POPCD distribution. The methodology used for these predictions is the same as previously described for analysis based on EOC-12 actual voltages; however, a SLB leak rate versus bobbin voltage correlation was applied as noted in Section 4.0. An updated leak rate and tube burst database that includes recent (1996 and 1997) data from plants A-1, A-2 and W-2 were used in the EOC-13 leak rate and tube burst probability projections. Projected results for EOC-13 conditions are summarized on Table 7-2. With a constant POD of 0.6, the limiting EOC-13 SLB leak rate projected is 1.0 gpm (room temperature), and it is predicted for SG-A which has the largest number of indications as well as the highest voltage indication returned to service for Cycle 13 operation. This limiting leak rate value was calculated using a leak rate versus bobbin voltage correlation, and it is an order of magnitude below the allowable SLB leakage limit of 8.0 gpm (room temperature) for Cycle 12. The limiting tube burst probability,  $1.6 \times 10^{-4}$ , is also predicted for SG-A which had 10 of the 14 largest indications found in the EOC-12 inspection; it is nearly 2 orders of magnitude below the NRC reporting guideline of  $10^{-2}$ .

Table 7-2 also includes SLB leak rates and tube burst probabilities calculated using the voltage dependent EPRI POPCD distribution. Application of the more realistic EPRI POPCD distribution to establish BOC-13 voltage distribution results in a reduction of SLB leak rate projections by about 25% and tube burst probability projections by about 50% relative to the projections based on a constant POD of 0.6.

EOC-13 SLB leak rates for all three SGs were also calculated using the methodology applied in the past in which leak rate is assumed to be independent of bobbin voltage, and these results are also shown in Table 7-2. It is evident that even the EOC-13 leak rates calculated with the old method remain below 50% of the allowable limit.

In summary, SLB leak rates and tube burst probabilities predicted for EOC-13 are one to two decades below their respective allowable limits.

**Table 7-1**  
**Beaver Valley Unit 1 1997 EOC-12 Outage**  
**Summary of Calculations of Tube Leak Rate and Burst Probability**

Steam Generator	POD	Number of Indications	Max. Volts	Burst Probability		SLB Leak Rate (gpm) <sup>(1)</sup>
				1 Tube	1 or More Tubes	
<b>EOC - 12 PROJECTIONS</b> (Based on ARC Database Presented in Reference 8-9)						
A	0.6	1513.5 <sup>(2)</sup>	2.9 <sup>(3)</sup>	$1.2 \times 10^{-4}$	$1.2 \times 10^{-4}$	4.3
B	0.6	1235.8 <sup>(2)</sup>	3.7 <sup>(3)</sup>	$1.8 \times 10^{-4}$	$1.8 \times 10^{-4}$	4.5
C	0.6	885.3 <sup>(2)</sup>	2.8 <sup>(3)</sup>	$1.0 \times 10^{-4}$	$1.0 \times 10^{-4}$	2.8
<b>EOC - 12 ACTUALS</b> (Based on ARC Database Updated to Include '96 Plant A-2 & '97 Plant A-1 Data)						
A	1	1241	2.5	$9.7 \times 10^{-5}$	$9.7 \times 10^{-5}$	2.4
						0.3 <sup>(4)</sup>
				$3.1 \times 10^{-5}$ <sup>(5)</sup>	$3.1 \times 10^{-5}$ <sup>(5)</sup>	1.9 <sup>(5)</sup>
B	1	914	1.8	$3.7 \times 10^{-5}$	$3.7 \times 10^{-5}$	1.3
						0.2 <sup>(4)</sup>
C	1	756	1.9	$5.8 \times 10^{-5}$	$5.8 \times 10^{-5}$	1.4
						0.2 <sup>(4)</sup>

- Notes:**
- (1) Equivalent volumetric rate at room temperature.
  - (2) Adjusted for POD.
  - (3) Projected Maximum voltages include NDE uncertainties from Monte Carlo.
  - (4) Utilizes leak rate correlation based on an updated database including '96 Farley-2, '97 Farley-1 and '96 Sequoyah-2 pulled tube exam data.
  - (5) Based on the database used for EOC-12 projections (presented in Reference 8-9).

**Table 7-2**  
**Beaver Valley Unit-1 October 1997 Outage**  
**Summary of Projected Tube Leak Rate and Burst Probability**  
**for EOC-13 - 250k Simulations**

Steam Generator	POD	No. of Indications <sup>(1)</sup>	Max. Volts <sup>(2)</sup>	Burst Probability		SLB Leak Rate (gpm) <sup>(3)</sup>
				1 Tube	1 or More Tubes	
<b>EOC - 13 PROJECTIONS<sup>(4,5)</sup></b>						
<b>(Leak Rate vs. Bobbin Voltage Correlation Applied)</b>						
A	0.6	1983	3.1	$1.6 \times 10^{-4}$	$1.6 \times 10^{-4}$	1.0
B	0.6	1474	2.7	$1.1 \times 10^{-4}$	$1.1 \times 10^{-4}$	0.7
C	0.6	1224	2.8	$9.9 \times 10^{-5}$	$9.9 \times 10^{-5}$	0.6
A	POPCD	1948	2.8	$7.8 \times 10^{-5}$	$7.8 \times 10^{-5}$	0.7
B	POPCD	1507	2.7	$9.0 \times 10^{-5}$	$9.5 \times 10^{-5}$	0.6
C	POPCD	1229	2.7	$7.9 \times 10^{-5}$	$7.9 \times 10^{-5}$	0.5
<b>EOC - 13 PROJECTIONS<sup>(6)</sup></b>						
<b>(Leak Rate Assumed Independent of Voltage)</b>						
A	0.6	1983	3.1	$1.8 \times 10^{-4}$	$1.8 \times 10^{-4}$	6.4
B	0.6	1474	2.7	$1.2 \times 10^{-4}$	$1.2 \times 10^{-4}$	4.9
C	0.6	1224	2.8	$1.5 \times 10^{-4}$	$1.5 \times 10^{-4}$	4.1

**Notes**

- (1) Number of indications adjusted for POD.
- (2) Voltages include NDE uncertainties from Monte Carlo analyses.
- (3) Equivalent volumetric rate at room temperature.
- (4) Leak rate and burst probability correlations for 7/8" tubes presented in Reference 8-8 applied. Database used includes 1996 Plants A-2 and W-2, and 1997 Plant A-1 data.
- (5) Based on a Projected Cycle 13 length of 500 EFPD.
- (6) Database applied includes 1996 Plant A-2 and 1997 Plant A-1 data. Tube burst probability is slightly different from that in Reference 8-8 as 1996 Plant W-2 data is not included.

## 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-96-07-009, "Beaver Valley Unit-1 1996 Alternate Repair Criteria 90-Day Report," Westinghouse Electric Corporation, July 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 EPRI Report NP 7480-L, Addendum 1, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate repair Limits," Electric Power Research Institute, November 1996.
- 8-5 U.S. N.R.C. Report, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 198 to Facility Operating License DPR-66 Duquesne Light Company, Ohio Edison Company and Pennsylvania Power Company, Beaver Valley Power Station, Unit No. 1 Docket No. 50-334", April 1, 1996.
- 8-6 Letter from B. W. Sheron, Nuclear Regulatory Commission, to A. Marion, Nuclear Energy Research Institute, dated February 9, 1996.
- 8-7 Document Identifier 51-1264500-00, "Probe Wear Monitoring at Beaver Valley Power Station Unit-1 October 1997 U1R12," Framatome Technologies, November 1997.
- 8-8 Letter from R. Clive Callaway, Nuclear Energy Research Institute, to Nuclear Regulatory Commission, "Updated ODSCC ARC Correlations for 7/8" Diameter Tubes," dated December 29, 1997.
- 8-9 Attachment to Duquesne Light Company letter to U. S. Nuclear Regulatory Commission, "Beaver Valley Power Station, Unit No. 1, Docket No. 50-334, License No. DPR-66, Steam Generator Pulled Tube Data (Supplemental) Supporting Alternate Plugging Criteria Implementation," dated March 27, 1996.

8-10 Letter from E. J. Sullivan, Nuclear Regulatory Commission, to D. J. Modeen, Nuclear Energy Research Institute, dated January 20, 1998.