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BEAVER VALLEY UNIT 1

1996 ALTERNATE REPAIR CRITERIA 90 DAY REPORT

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1.0 INTRODUCTION

This report provides the Beaver Valley Unit 1 steam generator tube support plate (TSP) bobbin voltage distribution summary, together with postulated Steam Line Break (SLB) leak rate and tube burst probability analysis results, in support of the implementation of a 2.0 volt Alternate Repair Criteria (ARC) for Cycle 12 as outlined in the NRC Generic Letter, Reference 9.1. Information required by the NRC Safety Evaluation Report (SER) is included in this report. Also provided are projections of bobbin voltage distributions, leak rates and burst probabilities for Cycle 12 operation. The methodology used in these evaluations is consistent with the NRC SER, Reference 9.3, Westinghouse generic methodology described in Reference 9.3, as well as the methodology reported in the prior ARC reports for Beaver Valley Unit-1 (References 9.2 and 9.4).

The results of the End of Cycle 11 (EOC-11) inspection are provided in Section 3. The actual EOC-11 voltage distributions as well as leak rates and tube burst probabilities calculated for those distributions are compared with the projections for EOC-11 conditions using the EOC-10 data. During this inspection, plugs were removed from previously repaired tubes, the tubes were reinspected, and those with indications satisfying the 2 volt repair limits were returned to service. The indication population returned to service from deplugged tubes are included in the Cycle 12 analyses. Leak rates and burst probabilities for the projected EOC-12 voltage distributions are reported in Section 7 and compared with allowable limits. The predicted steam generator (SG) tube leak rate and probability of burst during a postulated steam line break (SLB) at EOC-12 meet the regulatory requirements outlined in the NRC SER.

2.0 SUMMARY AND CONCLUSIONS

SLB leak rate and tube burst probability analyses were performed for the actual EOC-11 bobbin voltage distributions and for projected EOC-12 distributions. SG B with the largest indication detected (3.35 volts) was found to be the limiting SG at EOC-11, although SG A was projected to be the limiting SG and it also has the highest number of indications detected during the EOC-11 inspection. However, the differences in the results for those two SGs are small, with SLB leak rates based on the measured EOC-11 voltages being the same for the two SGs (1.50 gpm), while SG B yielded a slightly higher tube burst probability (6.48×10^{-5} vs. 6.07×10^{-5} for SG A) since it had one more tube burst than SG A in the 250,000 simulation Monte Carlo analysis performed for each SG. The corresponding results for SG C are well below those shown above for SGs A and B. SG B is also predicted to be limiting at EOC-12, with the highest number of indications, bobbin voltage amplitude, and leak rate and tube burst probability for postulated SLB conditions. EOC-12 SLB leak rate projected for SG B is equal to the SER acceptance limit of 4.50 gpm, however, alternate calculations with some of the conservatism in the present licensing database and method removed show much higher margins in the EOC-12 leak rates. The tube burst probability at EOC-12 is low, varying between 1.02 E-04 and 1.76 E-04 among the three SGs. These calculations show that ARC application at EOC-11 (actual distribution) and at EOC-12 (predicted for POD = 0.6) will satisfy NRC criteria for allowable leakage and burst probability.

A total of 1936 bobbin indications was reported for tubes in service during the Cycle 11 inspection. 242 of the 1936 bobbin indications were above 1.0 volt, and only three indications exceeded the 2.0 volt repair limit. 77 bobbin indications were RPC inspected, including the three indications above 2 volts, of which 43 were confirmed. 83 indications were repaired for tubes in service during Cycle 11, of which only two were repaired because of exceeding the 2 volt repair criteria. Accordingly, 1853 of the 1936 indications were returned to service for Cycle 12.

SG A with 849 indications (in the tubes in service during Cycle 11) had the highest number of indications at EOC-11. 96 of the 849 indications were reported as above 1.0 volt and only two indications had a voltage above 2 volts. 32 indications were RPC inspected and 21 were confirmed. 29 of the 849 indications were removed from service due to tube repairs, but only one of those was repaired because of exceeding the 2 volt repair limit for outside diameter stress corrosion cracking (ODSCC) at tube support plates (TSP).

During the outage, tubes previously plugged in accordance with prior repair criteria were deplugged, inspected and either returned to service in accordance with the 2 volt ARC criteria or replugged. Accordingly, 508 such indications (258 of them with a bobbin voltage above 1.0 V) were returned to service, for a total of 2361 indications returned to service for Cycle 12 operation in accordance with ARC criteria. The largest number of indications added from tube deplugging are in SG C (252), and the reason for this being a large number of tubes were already deplugged and returned to service from SGs A and B, but none from SG C, during the EOC-10 inspection.

Using the NRC mandated POD value of 0.6 to calculate the performance of the limiting SG during the next Beaver Valley Unit 1 operating cycle, the SLB tube leak rate is projected to be 4.5 gpm for SG B and the corresponding tube burst probability is projected to be 1.76×10^{-6} at EOC-12. These results meet the Beaver Valley Unit 1 ARC requirement for allowable tube leakage (4.5 gpm) and the NRC guideline for tube burst probability (1×10^{-2}); accordingly Cycle 12 operation of Beaver Valley Unit 1 is considered to be in compliance with the requirements of the NRC SER of Reference 9.3.

It is anticipated that a revision to the approved industry database (Reference 9.6) will be sent to the NRC in mid-August, 1996. Contained in this revision will be a discussion and justification for excluding the French datapoints when determining correlations for 7/8" diameter SG tubes. With the French data removed, the requirement for applying the SLB leak rate versus bobbin voltage correlation can be met. Therefore, the correlation can be used in leak rate calculations. The SLB tube leak rate at EOC-12 for SG B, the limiting SG, is projected to be 4.5 gpm using the currently approved database which does not result in a voltage dependent leak rate correlation. However, upon NRC acceptance, Duquesne Lights' intention is to use the updated database which excludes the French data. The SLB tube leak rate at EOC-12, utilizing the updated database which supports a voltage dependent correlation, for SG B is projected to be 0.52 gpm.

3.0 EOC-11 INSPECTION RESULTS AND VOLTAGE GROWTH RATES

3.1 EOC-11 INSPECTION RESULTS

In accordance with the ARC guidance provided by the NRC generic letter (Reference 9.1), the end of Cycle 11 (EOC-11) inspection of the Beaver Valley Unit 1 steam generators (SG) consisted of a complete 100% bobbin probe full length examination of all TSP intersections in the tube bundles of all three SGs. Rotating Pancake coil (RPC) examination was performed for all bobbin indications with amplitudes greater than 2 volts. The NRC ARC criteria in the recent SER for Beaver Valley Unit-1 (Reference 9.3) require that RPC confirmed indications above 2.0 volts bobbin amplitude and that all bobbin indications above 5.6 volts shall be plugged. Only three indications exceeded the 2 volts in the current inspection, and two of them were confirmed by RPC and plugged. Tubes previously plugged in accordance with prior repair criteria for ODSCC at TSPs were deplugged during this outage, inspected and either returned to service in accordance with the 2 volt repair criteria or replugged.

A summary of eddy current test (ECT) indication distributions for all steam generators is shown on Table 3-1. For those tubes that were in service for Cycle 11, Table 3-1 provides the number of field bobbin indications, the number of these field bobbin indications that were RPC inspected, the number of RPC confirmed indications, the number of indications in plugged tubes, the number of Cycle 11 in-service indications that remain active for Cycle 12, the indications recovered from deplugged tubes which were returned to service for Cycle 12, and the subsequent total indication population being returned to service (RTS) for the beginning of Cycle 12 (BOC-12). Overall, the combined data for the Beaver Valley Unit 1 steam generators show that:

- Out of a total of 1936 indications which were in-service during Cycle 11 and were identified during the EOC-11 inspection, 83 were removed from service, of which only two indications did not meet the 2 volt repair criteria (and the remaining were plugged for causes other than ODSCC at TSP intersections), leaving 1853 which were returned to service for Cycle 12. The largest indication was found in SG B and it had a bobbin amplitude of 3.35 volts.

- Of the 1936 indications, a total of 77 were RPC inspected, with 22 of the 77 above 1 volt.

- Of the 77 RPC inspected, a total of 43 were RPC confirmed.

- Additionally, 508 indications from deplugged tubes were recovered and returned to service, for a total of 2361 indications returned to service for Cycle 12 operation in accordance with ARC criteria.

- The largest number of indications added from tube deplugging are in SG C (252), and the reason for this being a large number of tubes were already deplugged and returned to service from SGs A and B, but none from SG C, during the EOC-10 inspection.

A review of Table 3-1 indicates that SG A has more total as well as higher amplitude BOC-12 indications (953, with 160 indications above 1.0 volt) than either of the other two SGs, thereby being the likely limiting SG at EOC-12.

Figure 3-1 shows the actual bobbin voltage distribution for tubes that were in service during Cycle 11, as determined from the EOC-11 ECT inspection, and SG A has a higher number of indications than the other two SGs. However, the largest bobbin indication found in the EOC-11 inspection (3.35 volts) was in SG B (shown in the 3.4 volt bin). Figure 3-2 shows the distribution of the EOC-11 bobbin indications which were plugged and taken out of service and Figure 3-3 shows the bobbin voltage distribution of indications in service during Cycle 11 RTS for BOC-12.

During the outage, tubes previously plugged in accordance with prior repair criteria for ODSCC at TSPs were deplugged, inspected and either returned to service in accordance with the 2 volt criteria or replugged; a summary of indications in those tubes is presented on Table 3-2. Accordingly, 508 such indications (with 258 above 1.0 volt and two above 2 volts bobbin amplitude) from all three SGs were returned to service for Cycle 12 in accordance with the 2 volt repair criteria. Figure 3-4 shows the bobbin voltage distribution for the deplugged indications which were returned to service for Cycle 12. The total number of indications in deplugged tubes returned to service for SG C is almost equal to the combined total of such indications for the remaining two SGs because a large number of tubes were already deplugged and returned to service in SGs A and B during the EOC-10 inspection (but none from SG C). Figure 3-5 shows the voltage distribution for all indications (those continuing from Cycle 11 service and those deplugged at EOC-11) which were RTS for Cycle 12.

The distribution of EOC-11 indications as a function of support plate elevation, summarized in Table 3-3 and illustrated on Figure 3-6, shows the predisposition of ODSCC to occur in the first few hot leg TSPs (1723 of the 1936 indications occurred in

the first two hot leg TSPs), although the mechanism does extend to higher TSPs. There were no bobbin indications reported in the cold leg. This distribution shows the predominant temperature dependence of ODSCC at Beaver Valley Unit 1, similar to that observed at other plants.

3.2 VOLTAGE GROWTH RATES

The bobbin voltage growth rates for the Beaver Valley Unit-1 steam generators, shown on Table 3-4, provide a comparison of average growth rates for the recent operating cycles; data for the last five cycles are provided. It is evident that for the cycle just completed (Cycle 11) there is a substantial increase in the indication population below 0.75 volts. This could be attributed to improved ECT practice which has resulted in more accuracy and discrimination of bobbin probe signals, so that more low voltage indications are being reported. The average growth rates decreased consistently between Cycles 7 through 10, but Cycle 11 shows a larger growth rate than Cycle 10. However, Cycle 11 has lower growth than prior Cycles 7 through 9.

Average growth rates for each SG during Cycle 11 are summarized on Table 3-5. Those growth rates vary between 7.7% and 23.6%, between SGs, with an overall average of 13.9%, on an effective full power year (EFPY) basis. The average growth for indications with a BOC bobbin voltage above 0.75 volt is 10.2% per EFPY and for indications below 0.75 volt it is 16.5% per EFPY. SG A had the highest average bobbin voltage at EOC-11 whereas SG B had the largest average growth during Cycle 11.

Another cycle growth comparison is provided in more detail by the cumulative probability distribution functions (CPDF) for Cycles 11 and 10 summarized on Tables 3-6 and 3-7, respectively, and also illustrated on Figure 3-7. Average growth rates for Cycle 11 are clearly higher than those observed for Cycle 10. The NRC generic letter recommends that the more conservative growth distribution from the last two cycles be used for projecting EOC distributions. Accordingly, Cycle 11 bobbin voltage growth rates will be used for predicting the EOC-12 conditions; these rates are developed from the 1996 EOC-11 inspection data and a reevaluation of the same indications from the previous (1995) inspection ECT signals.

Table 3-6 shows CPDF for each SG during Cycle 11, and the same data is presented in a graphical form on Figure 3-8. Clearly, growth rates for SG B are higher than those of the other two SGs. According to the Westinghouse ARC analysis methodology

presented in Reference 9.5, the larger of the composite growth rate for all SGs and the SG-specific growth rate should be used in projecting SLB leak rate and tube burst probability for individual SGs. Since the growth rates for SGs A and C are below the composite growth rate, the composite growth rate is applied to those two SGs to provide a conservative basis for predicting EOC-12 conditions. However, predictions for SG B are obtained using its own growth rate since it is higher than the composite rate.

3.3 PROBABILITY OF PRIOR CYCLE DETECTION (POPCD)

The inspection results at EOC-11 permit an evaluation of the probability of detection at the prior EOC-10 inspection. For ARC/APC 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 ARC 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-10 inspection can then be defined as:

$$\text{POPCD (EOC-10)} = \frac{\text{EOC-10 cycle reported indications confirmed by RPC in EOC-11 inspection} + \text{Indications confirmed and repaired in EOC-10 inspection}}{\{\text{Numerator}\} + \text{New indications RPC confirmed in EOC-11 inspection}}$$

POPCD is evaluated at the 1995 EOC-10 voltage values (from 1996 reevaluation for growth rate) since it is an EOC-10 POPCD assessment. The indications at EOC-10 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-11. It is also appropriate to include the plugged tubes for ARC applications since POD adjustments to define the BOC distribution are applied prior to reduction of the EOC indication distribution for plugged tubes. Indication in tubes deplugged and returned to service at EOC-11 are not included in the evaluation since it is not appropriate to include them.

It should be noted that the above POPCD definition includes all new EOC-11 indications not reported in the EOC-10 inspection. The new indications include EOC-10 indications present at detectable levels but not reported, indications present at EOC-10 below detectable levels and indications that initiated during Cycle 11. Thus, this definition, by including newly initiated indications, differs from the traditional POD definition. Since the newly initiated indications are appropriate for ARC applications, POPCD is an acceptable definition and eliminates the need to adjust the traditional POD for new indications.

The above definition for POPCD would be entirely appropriate if all EOC-11 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 1996 EOC-11 indications not RPC inspected since inclusion for the EOC-10 inspection could increase POPCD by including indications on a tube plugged for non-ODSCC causes. This POPCD can be obtained by replacing the EOC-11 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 1995 EOC-10 inspection data is shown on Figure 3-9 and summarized in Table 3-8. Figure 3-9 shows POPCD evaluated for both RPC confirmed indications only and for RPC confirmed plus not RPC inspected indications. Also shown is the EPRI POD developed by analyses of field indications for 3/4 inch diameter tubing in Model D SGs. From Table 3-8, it is seen that between 0.6 to 1.8 volts POPCD based on only RPC confirmed indications is significantly higher than POPCD based on RPC confirmed plus not RPC inspected indications, which is to be expected since only a small fraction of the indication not RPC inspected are RPC confirmed in that voltage range. The Beaver Valley Unit-1 POPCD defined using RPC confirmed plus not inspected indications is in good agreement with the EPRI POD while the distribution defined with RPC confirmed only indications is much above the EPRI POD.

In summary, the Beaver Valley Unit-1 EOC-10 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 volts, and it is in good agreement with the EPRI proposed POD. It is concluded that the POD applied for ARC leak and burst projections needs to be upgraded from the constant POD value of 0.6 to a voltage dependent POD.

3.4 ASSESSMENT OF RPC CONFIRMATION RATES

This section tracks the 1995 EOC-10 indications left in service at BOC-11 relative to RPC inspection results in 1996 at EOC-11. The data for the three SGs are shown individually in Tables 3-9 to 3-11, and the composite results for all SGs are given in Table 3-12. For 1995 bobbin indications left in service, the indications are tracked relative to 1995 RPC confirmed, 1995 RPC NDD, 1995 bobbin indications not RPC inspected and 1995 bobbin indications with no indication found in 1996. Also included are new 1996 indications. The table shows, for each category of indications, the number of indications RPC inspected and RPC confirmed in 1996 as well as the percentage of RPC confirmed indications.

The 1996 RPC confirmation rate for 1995 RPC NDD indications left in service was 66.7% for SGs A and B. For SG C, only one 1995 RPC NDD indication was RPC tested in 1996 and it was not confirmed. Thus, the overall confirmation rate for the 1995 RPC NDD indications was 60%. None of the 1995 RPC NDD indications RPC tested in 1996 had a bobbin voltage below 1.0 volt, so the data represent bobbin indications above 1.0 volt. This overall confirmation rate is slightly higher than that found for 1993 RPC NDD indications tested in 1995 (50.9 %) as well as that for 1991 to 1993 Cycle 9 indications (27.2%, Reference 9.2). For successive ARC inspections at other plants, the confirmation rate for RPC NDD indications left in service was typically < 40%.

The NRC SER (Reference 9.3) allows for consideration of only a fraction of RPC NDD indications from 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. Thus, the fraction that can be applied for 1995 RPC NDD indications is 0.7.

3.5 NDE UNCERTAINTIES

The NDE uncertainties applied for the EOC-11 voltage projections in this report are those given in the prior Beaver Valley-1 ARC reports (References 9.1 and 9.4). 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 used to project the EOC-11 voltage distributions.

Table 3-1
Beaver Valley Unit 1 1996 EOC-11
Summary of Inspection and Repair For Tubes in Service During Cycle 11

Voltage Bin	Steam Generator A							Steam Generator B						
	In-Service During Cycle 11					EOC-11	Cycle 12	In-Service During Cycle 11					EOC-11	Cycle 12
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Deplugged Tubes Returned to Service	All Tubes# Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Deplugged Tubes Returned to Service	All Tubes# Returned to Service
0.2	4	0	0	0	4	0	4	13	0	0	1	12	1	13
0.3	49	1	0	1	48	2	50	34	2	0	2	32	1	33
0.4	102	3	3	1	101	3	104	64	2	0	6	58	1	59
0.5	122	4	2	4	118	8	126	92	1	1	3	89	4	93
0.6	130	3	2	4	126	8	134	90	3	2	4	86	5	91
0.7	116	3	3	5	111	8	119	90	1	1	9	81	10	91
0.8	88	2	0	3	85	9	94	80	1	1	7	73	9	82
0.9	76	3	1	3	73	13	86	67	2	2	3	64	7	71
1	66	3	3	1	65	11	76	55	1	1	5	50	7	57
1.1	41	2	2	3	38	6	44	41	3	3	2	39	12	51
1.2	26	5	3	2	24	9	33	21	1	1	1	20	15	35
1.3	10	0	0	0	10	11	21	20	1	0	1	19	10	29
1.4	7	0	0	1	6	13	19	11	0	0	1	10	10	20
1.5	2	0	0	0	2	5	7	9	2	1	0	9	5	14
1.6	2	0	0	0	2	10	12	4	0	0	1	3	11	14
1.7	4	0	0	0	4	7	11	4	0	0	0	4	5	9
1.8	1	0	0	0	1	5	6	1	0	0	0	1	2	3
1.9	1	1	1	0	1	4	5	1	0	0	0	1	5	6
2	0	0	0	0	0	1	1	0	0	0	0	0	2	2
2.1	1	1	1	1	0	0	0	0	0	0	0	0	1	1
2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.3	1	1	0	0	1	0	1	0	0	0	0	0	0	0
3.4	0	0	0	0	0	0	0	1	1	1	1	0	0	0
Total	849	32	21	29	820	133	953	698	21	14	47	651	123	774
> 1V	96	10	7	7	89	71	160	113	8	6	7	106	78	184
> 2V	2	2	1	1	1	0	1	1	1	1	1	0	1	1

Voltage Bin	Steam Generator C							Composite of All Three Steam Generator Data						
	In-Service During Cycle 11					EOC-11	Cycle 12	In-Service During Cycle 11					EOC-11	Cycle 12
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Deplugged Tubes Returned to Service	All Tubes# Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Deplugged Tubes Returned to Service	All Tubes# Returned to Service
0.2	3	0	0	0	3	1	4	20	0	0	1	19	2	21
0.3	24	0	0	0	24	10	34	107	3	0	3	104	13	117
0.4	47	0	0	0	47	14	61	213	5	3	7	206	18	224
0.5	51	0	0	2	49	14	63	265	5	3	9	256	26	282
0.6	62	1	1	1	61	20	81	282	7	5	9	273	33	306
0.7	59	8	2	1	58	22	80	265	12	6	15	250	40	290
0.8	45	8	3	0	45	23	68	213	11	4	10	203	41	244
0.9	37	2	1	2	35	20	55	180	7	4	8	172	40	212
1	28	1	0	1	27	19	46	149	5	4	7	142	37	179
1.1	15	4	1	0	15	21	36	97	9	6	5	92	39	131
1.2	8	0	0	0	8	19	27	55	6	4	3	52	43	95
1.3	4	0	0	0	4	12	16	34	1	0	1	33	33	66
1.4	4	0	0	0	4	16	20	22	0	0	2	20	39	59
1.5	0	0	0	0	0	11	11	11	2	1	0	11	21	32
1.6	1	0	0	0	1	10	11	7	0	0	1	6	31	37
1.7	0	0	0	0	0	7	7	8	0	0	0	8	19	27
1.8	1	0	0	0	1	8	9	3	0	0	0	3	15	18
1.9	0	0	0	0	0	3	3	2	1	1	0	2	12	14
2	0	0	0	0	0	1	1	0	0	0	0	0	4	4
2.1	0	0	0	0	0	0	0	1	1	1	1	0	1	1
2.2	0	0	0	0	0	1	1	0	0	0	0	0	1	1
2.3	0	0	0	0	0	0	0	1	1	0	0	1	0	1
3.4	0	0	0	0	0	0	0	1	1	1	1	0	0	0
Total	389	24	8	7	382	252	634	1936	77	43	83	1853	508	2361
> 1V	33	4	1	0	33	109	142	242	22	14	14	228	258	486
> 2V	0	0	0	0	0	1	1	3	3	2	2	1	2	3

Includes indications in deplugged tubes returned to service

Table 3 - 2
Beaver Valley Unit 1 1996 EOC-11
Summary of Inspection and Repair For Tubes Deplugged at EOC-11

Voltage Bin	Steam Generator A					Steam Generator B					Steam Generator C					Combined Data from All Three SGs				
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service
0.2	0	0	0	0	0	1	0	0	0	1	2	0	0	1	1	3	0	0	1	2
0.3	2	0	0	0	2	3	0	0	2	1	10	0	0	0	10	15	0	0	2	13
0.4	3	0	0	0	3	3	0	0	2	1	16	0	0	2	14	22	0	0	4	18
0.5	8	0	0	0	8	8	0	0	4	4	17	0	0	3	14	33	0	0	7	26
0.6	8	0	0	0	8	9	0	0	4	5	22	0	0	2	20	39	0	0	6	33
0.7	8	0	0	0	8	14	0	0	4	10	23	0	0	1	22	45	0	0	5	40
0.8	10	0	0	1	9	14	0	0	5	9	26	0	0	3	23	50	0	0	9	41
0.9	18	0	0	5	13	14	0	0	7	7	26	0	0	6	20	58	0	0	18	40
1	13	0	0	2	11	13	0	0	6	7	21	0	0	2	19	47	0	0	10	37
1.1	9	0	0	3	6	14	0	0	2	12	23	0	0	2	21	46	0	0	7	39
1.2	10	1	1	1	9	19	1	1	4	15	21	0	0	2	19	50	2	2	7	43
1.3	11	1	1	0	11	14	0	0	4	10	14	0	0	2	12	39	1	1	6	33
1.4	15	0	0	2	13	10	1	1	0	10	16	0	0	0	16	41	1	1	2	39
1.5	5	0	0	0	5	6	0	0	1	5	13	0	0	2	11	24	0	0	3	21
1.6	10	0	0	0	10	12	1	1	1	11	12	0	0	2	10	34	1	1	3	31
1.7	7	0	0	0	7	6	2	2	1	5	7	0	0	0	7	20	2	2	1	19
1.8	6	0	0	1	5	3	0	0	1	2	9	0	0	1	8	18	0	0	3	15
1.9	4	0	0	0	4	7	0	0	2	5	4	0	0	1	3	15	0	0	3	12
2	1	0	0	0	1	4	1	1	2	2	1	0	0	0	1	6	1	1	2	4
2.1	3	3	3	3	0	3	2	2	2	1	7	7	6	7	0	13	12	11	12	1
2.2	5	5	5	5	0	2	2	2	2	0	5	5	4	4	1	12	12	11	11	1
2.3	0	0	0	0	0	5	5	5	5	0	2	2	2	2	0	7	7	7	7	0
2.4	1	1	1	1	0	4	4	4	4	0	2	2	1	2	0	7	7	6	7	0
2.5	0	0	0	0	0	3	3	3	3	0	1	1	1	1	0	4	4	4	4	0
2.6	1	1	1	1	0	2	2	2	2	0	2	2	2	2	0	5	5	5	5	0
2.7	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	3	3	3	3	0
2.8	0	0	0	0	0	2	2	2	2	0	1	1	1	1	0	3	3	3	3	0
2.9	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
3.4	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0
3.7	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0
3.9	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0
4.4	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0
Total	161	14	14	28	133	198	29	29	75	123	306	23	20	54	252	665	66	63	157	508
> 1V	91	14	14	20	71	119	29	29	41	78	143	23	20	34	109	353	66	63	95	258
> 2V	13	12	12	13	0	24	23	23	23	1	23	23	20	22	1	60	58	55	58	2

Table 3 -3
Beaver Valley Unit 1 1996 Outage
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 11

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	503	2.21	0.69	0.550	0.043	396	3.35	0.76	0.830	0.140
2H	278	1.69	0.62	0.360	0.042	206	1.46	0.67	0.630	0.127
3H	49	1.27	0.67	0.330	0.060	58	1.61	0.61	0.500	0.084
4H	10	1.54	0.64	0.320	0.073	31	1.23	0.58	0.280	0.088
5H	7	0.74	0.45	0.150	0.071	5	0.85	0.44	0.130	0.028
6H	0	-	-	-	-	1	0.52	0.52	0.050	0.050
7H	2	0.31	0.28	0.080	-0.020	1	0.35	0.35	0.000	0.000
Total	849					698				

Tube Support Plate	Steam Generator C					Composite of All Three SGs				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
1H	207	1.79	0.71	0.410	0.072	1106	3.35	0.72	0.83	0.083
2H	133	1.51	0.60	0.350	0.069	617	1.69	0.63	0.63	0.076
3H	35	1.14	0.55	0.310	0.091	142	1.61	0.61	0.5	0.077
4H	6	1.1	0.61	0.290	0.103	47	1.54	0.60	0.32	0.087
5H	5	0.3	0.26	0.090	0.018	17	0.85	0.39	0.15	0.043
6H	3	0.39	0.35	0.070	0.043	4	0.52	-	0.07	-
7H	0	-	-	-	-	3	0.35	-	0.08	-
Total	389					1936				

Table 3 - 4
Beaver Valley Unit-1 1996 Outage
Average Voltage Growth History
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 11 (1995 - 1996) - 352.94 EFPD					
Entire Voltage Range	1936	0.60	0.08	0.08	13.5%	13.9%
V_{BOC} < .75 Volts	1434	0.48	0.08	0.08	15.9%	16.5%
≥ .75 Volts	502	0.94	0.09	0.10	9.9%	10.2%
	Cycle 10 (1993 - 1995) - 435.79 EFPD					
Entire Voltage Range	1089	0.66	0.02	0.02	3.0%	2.5%
V_{BOC} < .75 Volts	751	0.50	0.04	0.03	8.0%	6.7%
≥ .75 Volts	338	1.01	-0.01	-0.01	-1.0%	-0.8%
	Cycle 9 (1991 - 1993) - 492.75 EFPD					
Entire Voltage Range	1125	0.57	0.09	0.07	15.8%	11.7%
V_{BOC} < .75 Volts	918	0.47	0.09	0.07	19.1%	14.2%
≥ .75 Volts	207	1.02	0.09	0.07	8.8%	6.5%
	Cycle 8 (1989 - 1991) - 390.82 EFPD					
Entire Voltage Range	952	0.95	0.18	0.17	18.9%	17.7%
V_{BOC} < .75 Volts	366	0.58	0.16	0.15	27.6%	25.8%
≥ .75 Volts	586	[illegible]	0.19	0.18	16.1%	15.0%
	Cycle 7 (1987 - 1989) - 438.3 EFPD					
Entire Voltage Range	918	0.66	0.29	0.24	43.9%	36.6%
V_{BOC} < .75 Volts	622	0.49	0.27	0.23	55.1%	45.9%
≥ .75 Volts	296	1.01	0.34	0.28	33.7%	28.1%

Table 3 - 5
Beaver Valley Unit -1 1996 Outage
Average Voltage Growth During Cycle 11

	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	1936	0.60	0.080	0.083	13.3%	13.9%
V_{BOC} < .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%
	Steam Generator A					
Entire Voltage Range	849	0.62	0.044	0.046	7.5%	7.7%
V_{BOC} < .75 Volts	611	0.48	0.049	0.051	10.4%	10.8%
≥ .75 Volts	238	0.96	0.033	0.034	3.6%	3.7%
	Steam Generator B					
Entire Voltage Range	698	0.58	0.128	0.133	22.8%	23.6%
V_{BOC} < .75 Volts	524	0.47	0.109	0.113	24.2%	25.1%
≥ .75 Volts	174	0.93	0.185	0.192	20.7%	21.4%
	Steam Generator C					
Entire Voltage Range	389	0.57	0.072	0.075	13.0%	13.5%
V_{BOC} < .75 Volts	299	0.47	0.072	0.075	15.8%	16.3%
≥ .75 Volts	90	0.91	0.072	0.075	8.2%	8.5%

* Based on Cycle 11 duration of 352.94 EFPD

Table 3 - 6
Beaver Valley Unit 1
Signal Growth Statistics For Cycle 11 ('95 to '96) on EFPY Basis

Delta Volts	Steam Generator A		Steam Generator B	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	0	0.000	0	0.000
-0.4	2	0.002	0	0.000
-0.3	3	0.006	0	0.000
-0.2	13	0.021	1	0.001
-0.1	42	0.071	4	0.007
0	206	0.313	87	0.132
0.1	387	0.769	258	0.501
0.2	144	0.939	180	0.759
0.3	32	0.976	104	0.908
0.4	15	0.994	36	0.960
0.5	4	0.999	17	0.984
0.6	1	1.000	8	0.996
0.7			1	0.997
0.8			1	0.999
0.9			1	1.000
Total	**849**		**698**	

Delta Volts	Steam Generator C		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	0	0.000	0	0.000
-0.4	0	0.000	2	0.001
-0.3	0	0.000	3	0.003
-0.2	1	0.003	15	0.010
-0.1	11	0.031	57	0.040
0	77	0.229	370	0.231
0.1	180	0.692	825	0.657
0.2	75	0.884	399	0.863
0.3	33	0.969	169	0.950
0.4	11	0.997	62	0.982
0.5	1	1.000	22	0.994
0.6			9	0.998
0.7			1	0.999
0.8			1	0.999
0.9			1	1.000
Total	389		1936	

Table 3 -7
Beaver Valley Unit 1
Signal Growth Statistics For Cycle 10 ('93 to '95) on EFPY Basis

Delta Volts	Steam Generator A		Steam Generator B	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	1	0.002	0	0.000
-0.4	3	0.008	0	0.000
-0.3	1	0.010	2	0.005
-0.2	13	0.037	7	0.023
-0.1	53	0.147	23	0.080
0	181	0.521	113	0.363
0.1	172	0.876	166	0.778
0.2	44	0.967	64	0.938
0.3	14	0.996	20	0.988
0.4	1	0.998	4	0.998
0.5	1	1.000	1	1.000
Total	484		400	
Delta Volts	Steam Generator C		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	0	0.000	1	0.001
-0.4	0	0.000	3	0.004
-0.3	0	0.000	3	0.006
-0.2	1	0.005	21	0.026
-0.1	14	0.073	90	0.108
0	57	0.351	351	0.431
0.1	96	0.820	434	0.829
0.2	28	0.956	136	0.954
0.3	6	0.985	40	0.991
0.4	2	0.995	7	0.997
0.5	1	1.000	3	1
Total	205		1089	

Table 3-8
Beaver Valley Unit - 1
1996 EOC-11 Evaluation for Probability of Prior Cycle Detection (EOC-10)
Composite of All Steam Generator Data

Voltage Bin	New Indications		1996 Bobbin, Field Call in 1995		1995 Bobbin	POPCD			
	1996 RPC Confirmed	1996 RPC Confirmed plus not Inspected	1996 RPC Confirmed	1996 RPC Confirmed plus not Inspected	1995 Confirmed and Plugged	RPC Confirmed		RPC Confirmed Plus Not Inspected	
						Fraction	Count	Fraction	Count
> 0 - 0.2	0	39	0	11	0	-	0 / 0	0.220	11 / 50
0.2 - 0.4	6	271	0	187	3	0.333	3 / 9	0.412	190 / 461
0.4 - 0.6	8	239	3	376	10	0.619	13 / 21	0.618	386 / 625
0.6 -0.8	4	110	7	315	19	0.867	26 / 30	0.752	334 / 444
0.8 - 1.0	1	42	8	226	18	0.963	26 / 27	0.853	244 / 286
1.0 - 1.2	1	16	2	37	50	0.981	52 / 53	0.845	87 / 103
1.2 - 1.4	0	4	0	16	26	1	26 / 26	0.913	42 / 46
1.4 - 1.6	0	1	1	5	19	1	20 / 20	0.960	24 / 25
1.6 - 1.8	0	1	0	5	11	1	11 / 11	0.941	16 / 17
1.8 - 2.0	0	0	1	1	5	1	6 / 6	1	6 / 6
2.0 - 2.2	0	0	0	0	5	1	5 / 5	1	5 / 5
2.2 - 2.5	0	0	0	0	4	1	4 / 4	1	4 / 4
2.5 - 3.0	0	0	1	1	5	1	6 / 6	1	6 / 6
3.0 - 4.0	0	0	0	0	6	1	6 / 6	1	6 / 6
4.0 - 5.5	0	0	0	0	5	1	5 / 5	1	5 / 5
TOTAL	20	723	23	1180	186				
Total > 1	1	22	5	65	136				

Table 3-9
Beaver Valley Unit 1
Analysis of RPC Data from 1995 and 1996 Inspections
Steam Generator A

Group of Indications	Total 1995 Bobbin Indication	Total 1996 Bobbin Indication	Total 1996 RPC Inspected	Total 1996 RPC Confirmed	Percent 1996 RPC Confirmed
Less than or Equal to 1.0 Volt in 1996					
'95 Bobbin Left in Service	459	459	11	6	54.5
- '95 RPC Confirmed	63	63	1	1	100.0
- '95RPC NDD	25	25	0	0	-
- '95 RPC Not Inspected	371	371	10	5	50.0
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	294	11	8	72.7
Sum of All '96 Indication	459	753	22	14	63.6
Greater than 1.0 Volt in 1996					
'95 Bobbin Left in Service	76	76	8	6	75.0
- '95 RPC Confirmed	29	29	2	2	100.0
- '95RPC NDD	36	36	6	4	66.7
- '95 RPC Not Inspected	11	11	0	0	-
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	20	2	1	50.0
Sum of All '96 Indication	76	96	10	7	70.0
All Voltages in 1996					
'95 Bobbin Left in Service	535	535	19	12	63.2
- '95 RPC Confirmed	92	92	3	3	100.0
- '95RPC NDD	61	61	6	4	66.7
- '95 RPC Not Inspected	382	382	10	5	50.0
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	314	13	9	69.2
Sum of All '96 Indication	535	849	32	21	65.6

* Indications split is based on '95 bobbin voltage

Table 3-10
Beaver Valley Unit 1
Analysis of RPC Data from 1995 and 1996 Inspections
Steam Generator B

Group of Indications	Total 1995 Bobbin Indication	Total 1996 Bobbin Indication	Total 1996 RPC Inspected	Total 1996 RPC Confirmed	Percent 1996 RPC Confirmed
Less than or Equal to 1.0 Volt in 1996					
'95 Bobbin Left in Service	370	370	7	3	42.9
- '95 RPC Confirmed	47	47	0	0	-
- '95RPC NDD	24	24	0	0	-
- '95 RPC Not Inspected	299	299	7	3	42.9
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	215	6	5	83.3
Sum of All '96 Indication	370	585	13	8	61.5
Greater than 1.0 Volt in 1996					
'95 Bobbin Left in Service	100	100	6	5	83.3
- '95 RPC Confirmed	35	35	1	1	100.0
- '95RPC NDD	28	28	3	2	66.7
- '95 RPC Not Inspected	37	37	2	2	100.0
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	13	2	1	50.0
Sum of All '96 Indication	100	113	8	6	75.0
All Voltages in 1996					
'95 Bobbin Left in Service	470	470	13	8	61.5
- '95 RPC Confirmed	82	82	1	1	100.0
- '95RPC NDD	52	52	3	2	66.7
- '95 RPC Not Inspected	336	336	9	5	55.6
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	228	6	6	75.0
Sum of All '96 Indication	470	698	21	14	66.7

* Indications split is based on '95 bobbin voltage

Table 3-11
Beaver Valley Unit 1
Analysis of RPC Data from 1995 and 1996 Inspections
Steam Generator C

Group of Indications	Total 1995 Bobbin Indication	Total 1996 Bobbin Indication	Total 1996 RPC Inspected	Total 1996 RPC Confirmed	Percent 1996 RPC Confirmed
Less than or Equal to 1.0 Volt In 1996					
'95 Bobbin Left in Service	172	172	9	2	22.2
- '95 RPC Confirmed	2	2	0	0	-
- '95RPC NDD	1	1	0	0	-
- '95 RPC Not Inspected	169	169	9	2	22.2
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	184	11	5	45.5
Sum of All '96 Indication	172	356	20	7	35.0
Greater than 1.0 Volt In 1996					
'95 Bobbin Left in Service	24	24	4	1	25.0
- '95 RPC Confirmed	0	0	0	0	-
- '95RPC NDD	7	7	1	0	0.0
- '95 RPC Not Inspected	17	17	3	1	33.3
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	9	0	0	-
Sum of All '96 Indication	24	33	4	1	25.0
All Voltages In 1996					
'95 Bobbin Left in Service	196	196	13	3	23.1
- '95 RPC Confirmed	2	2	0	0	-
- '95RPC NDD	8	8	1	0	0.0
- '95 RPC Not Inspected	186	186	12	3	25.0
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	193	11	5	45.5
Sum of All '96 Indication	196	389	24	8	33.3

* Indications split is based on '95 bobbin voltage

Table 3-12
Beaver Valley Unit 1
Analysis of RPC Data from 1995 and 1996 Inspections
Composite of All Steam Generator Data

Group of Indications	Total 1995 Bobbin Indication	Total 1996 Bobbin Indication	Total 1996 RPC Inspected	Total 1996 RPC Confirmed	Percent 1996 RPC Confirmed
Less than or Equal to 1.0 Volt in 1996					
'95 Bobbin Left in Service	1001	1001	27	11	40.7
- '95 RPC Confirmed	112	112	1	1	100.0
- '95RPC NDD	50	50	0	0	-
- '95 RPC Not Inspected	839	839	26	10	38.5
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	693	28	18	64.3
Sum of All '96 Indication	1001	1694	55	29	52.7
Greater than 1.0 Volt In 1996					
'95 Bobbin Left in Service	200	200	18	12	66.7
- '95 RPC Confirmed	64	64	3	3	100.0
- '95RPC NDD	64	71	10	6	60.0
- '95 RPC Not Inspected	65	65	5	3	60.0
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	42	4	2	50.0
Sum of All '96 Indication	200	242	22	14	63.6
All Voltages In 1996				0	
'95 Bobbin Left in Service	1201	1201	45	23	51.1
- '95 RPC Confirmed	176	176	4	4	100.0
- '95RPC NDD	121	121	10	6	60.0
- '95 RPC Not Inspected	904	904	31	13	41.9
- No '96 Bobbin *	0	-	-	-	-
New '96 Indication	-	735	32	20	62.5
Sum of All '96 Indication	1201	1936	77	43	55.8

* Indications split is based on '95 bobbin voltage

Figure 3 -1
Beaver Valley Unit -1 1996 Outage
Bobbin Voltage Distributions for Tubes in Service During Cycle 11

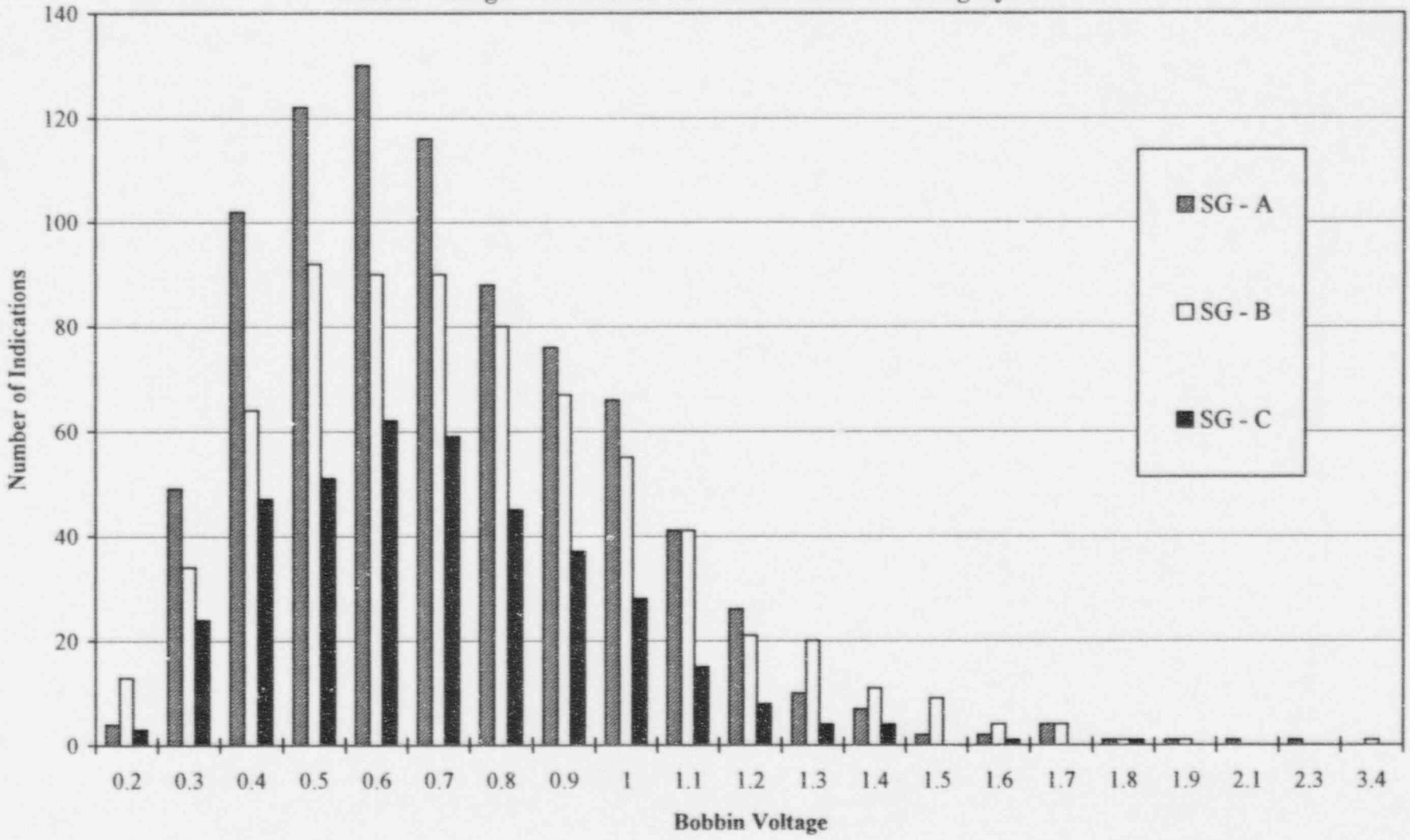


Figure 3 -2
Beaver Valley Unit -1 1996 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 11 Service

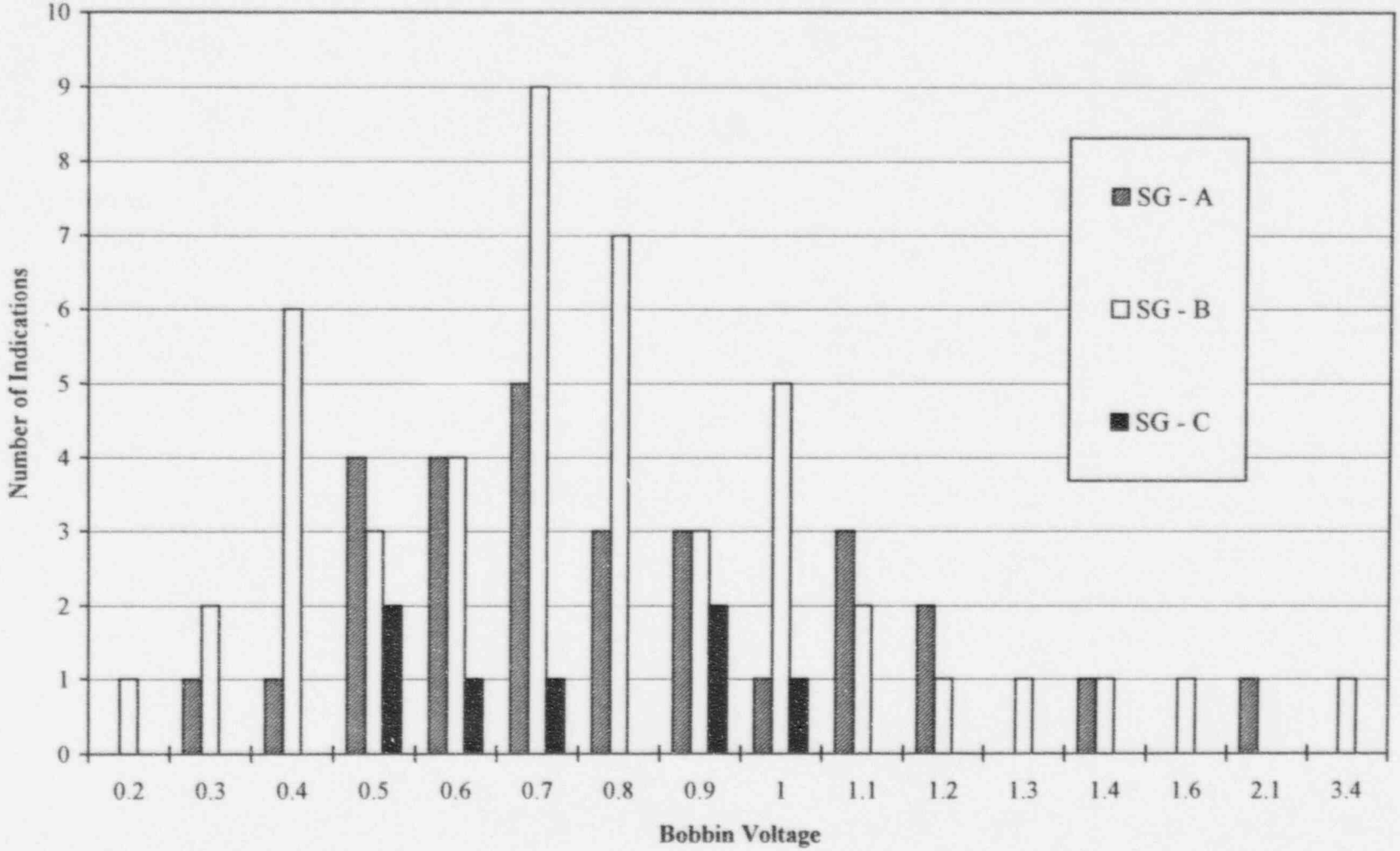


Figure 3 -3
Beaver Valley Unit -1 1996 Outage
Bobbin Voltage Distributions for Tubes in Service During Cycle 11 and RTS for Cycle 12

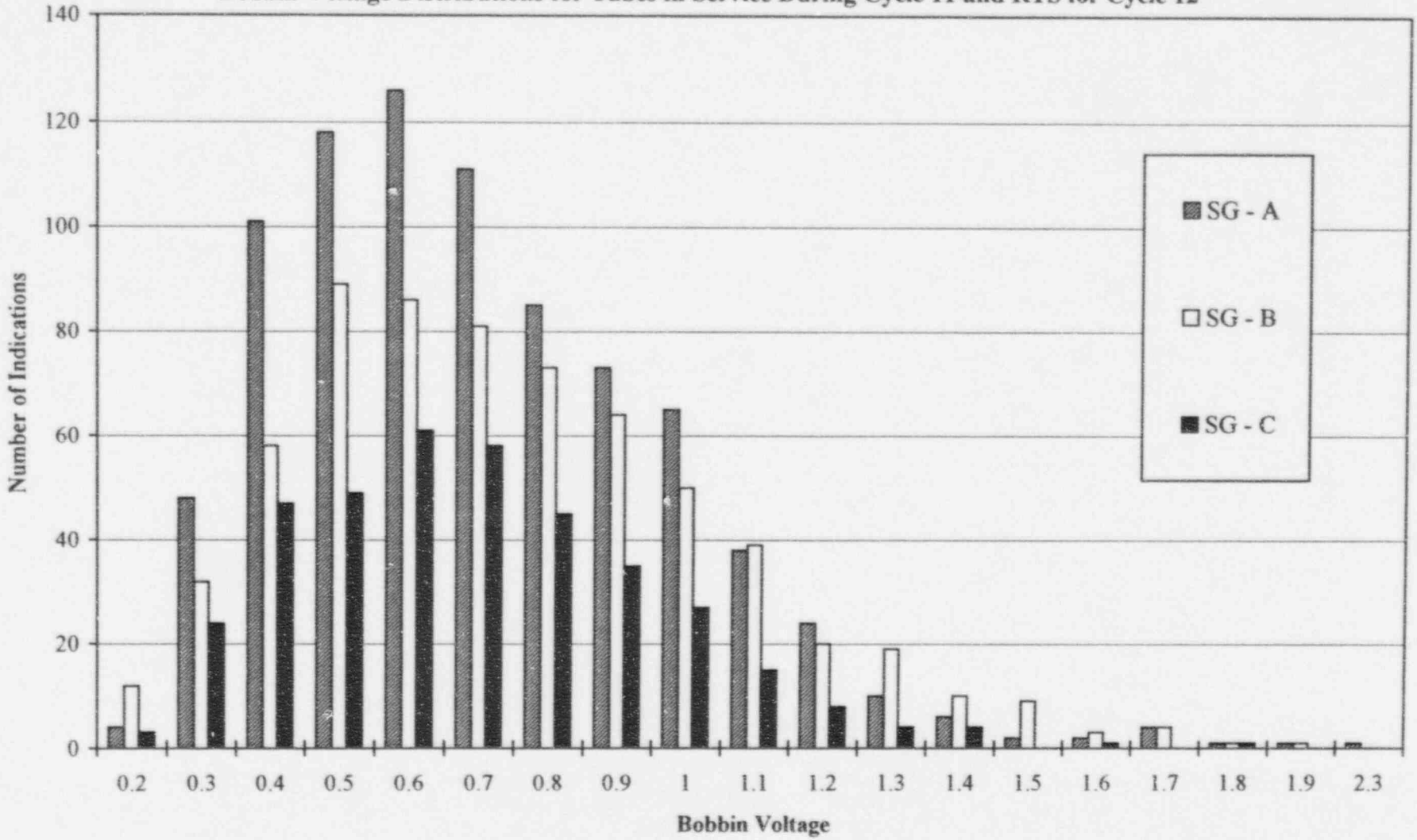


Figure 3 - 4
Beaver Valley Unit -1 1996 Outage
Bobbin Voltage Distributions for Deplugged Tubes Returned to Service for Cycle 12 Operation

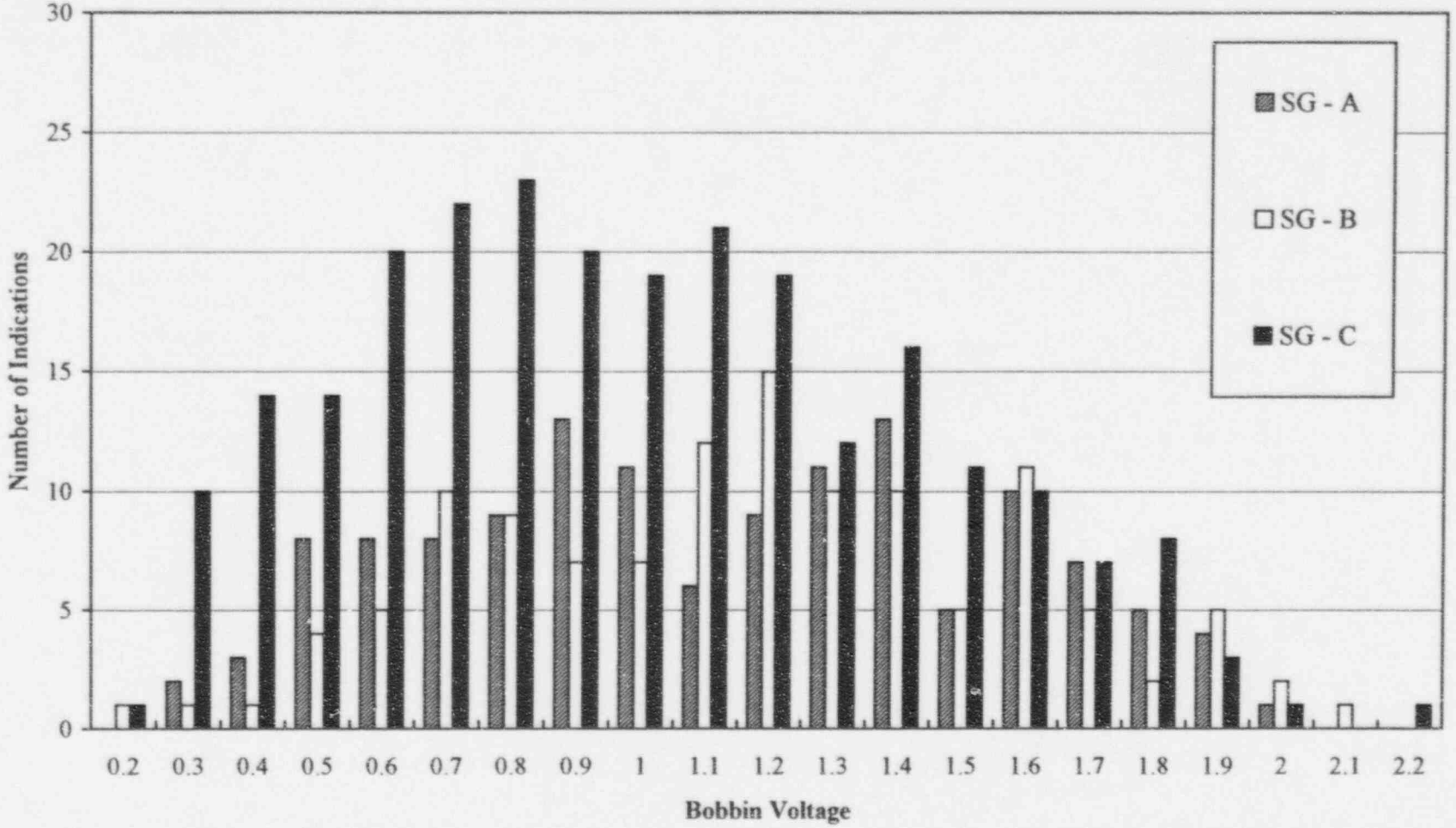


Figure 3 - 5
Beaver Valley Unit -1 1996 Outage
Bobbin Voltage Distributions for All Tubes Returned to Service at BOC-12

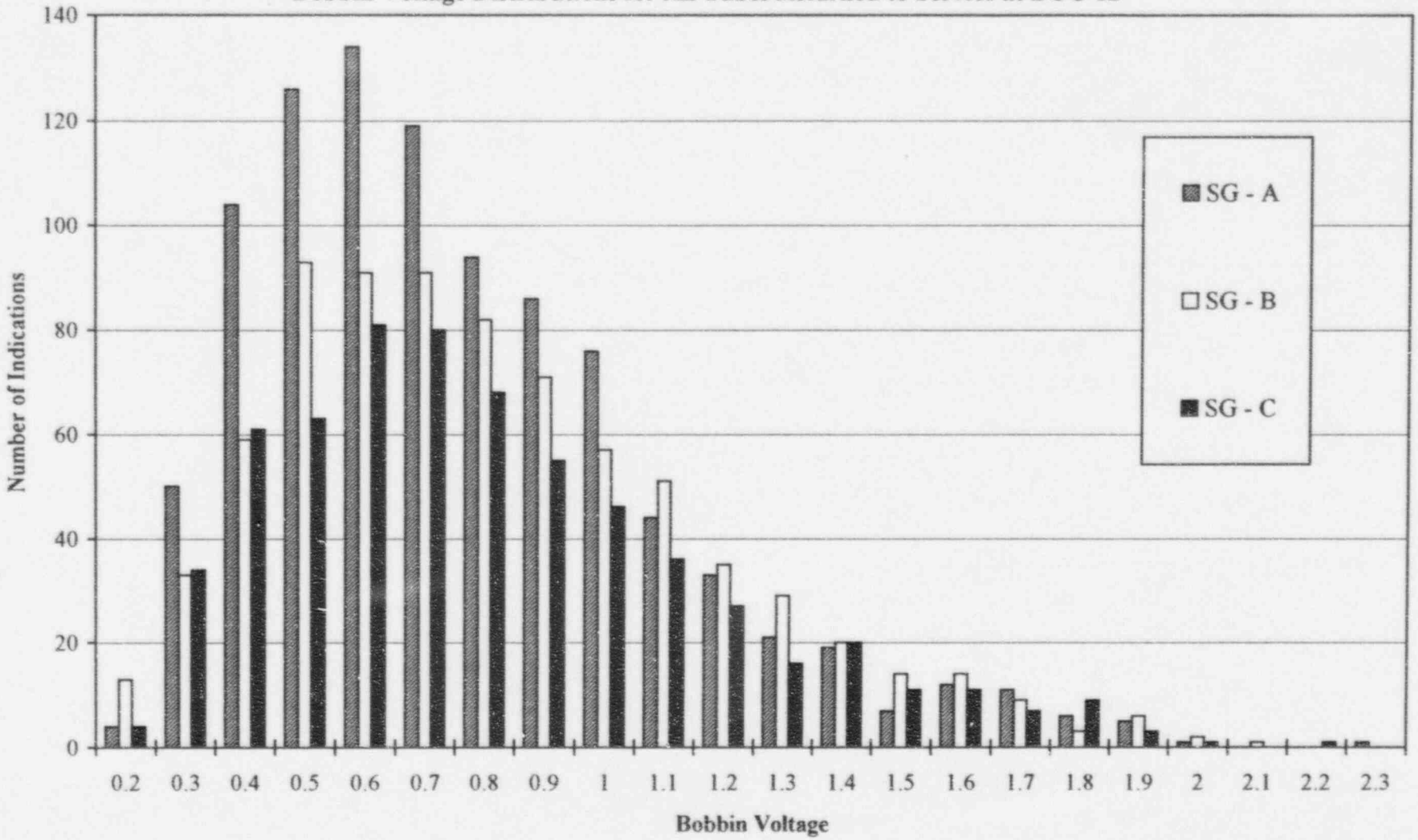


Figure 3 - 6
Beaver Valley Unit 1 1995 Outage
ODSCC Axial Distributions for Tubes in Service During Cycle 11

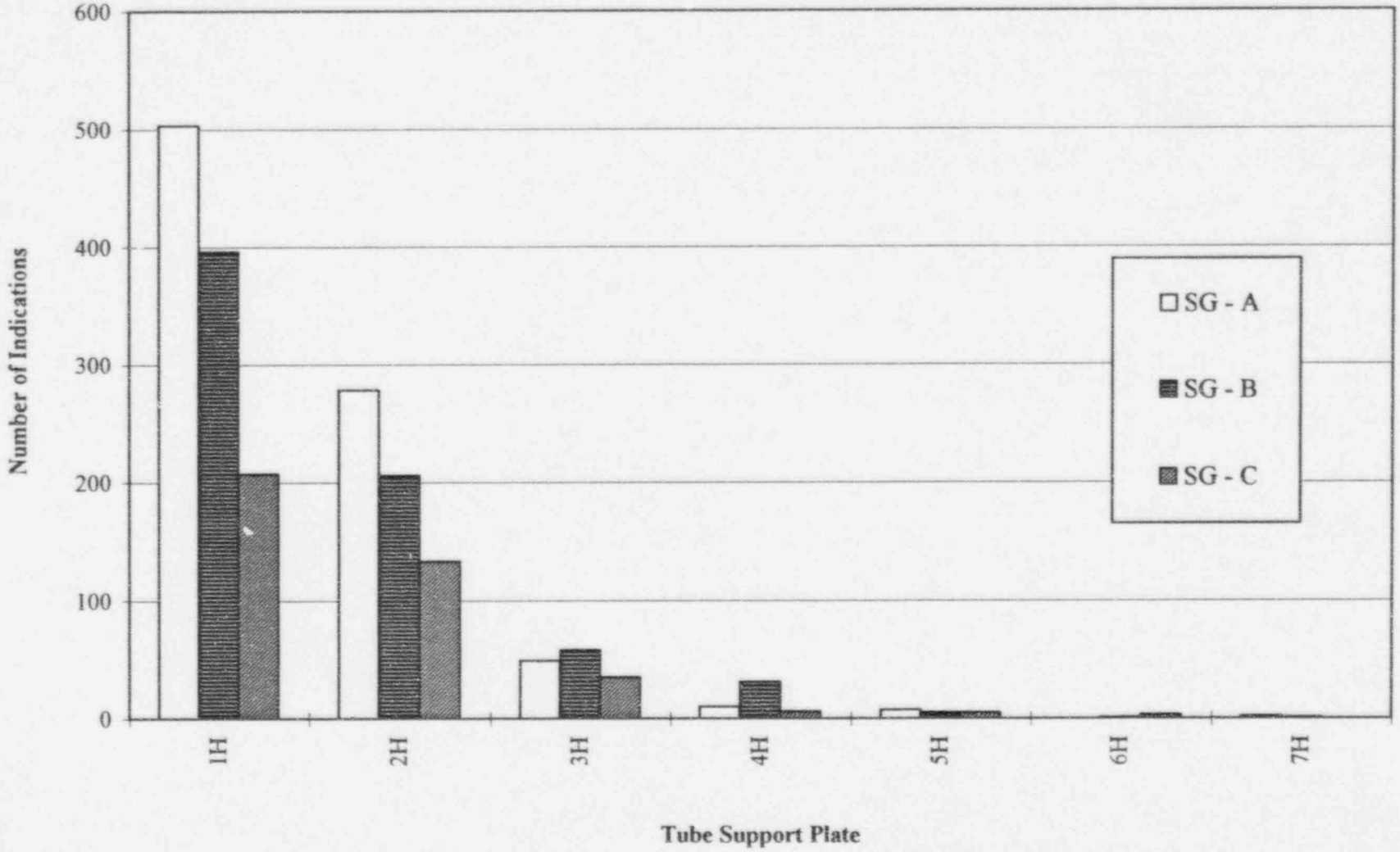


Figure 3-7
Beaver Valley Unit - 1
Cumulative Probability Distributions for Voltage Growth History on an EFPY Basis
Composite of All Three Steam Generator Data

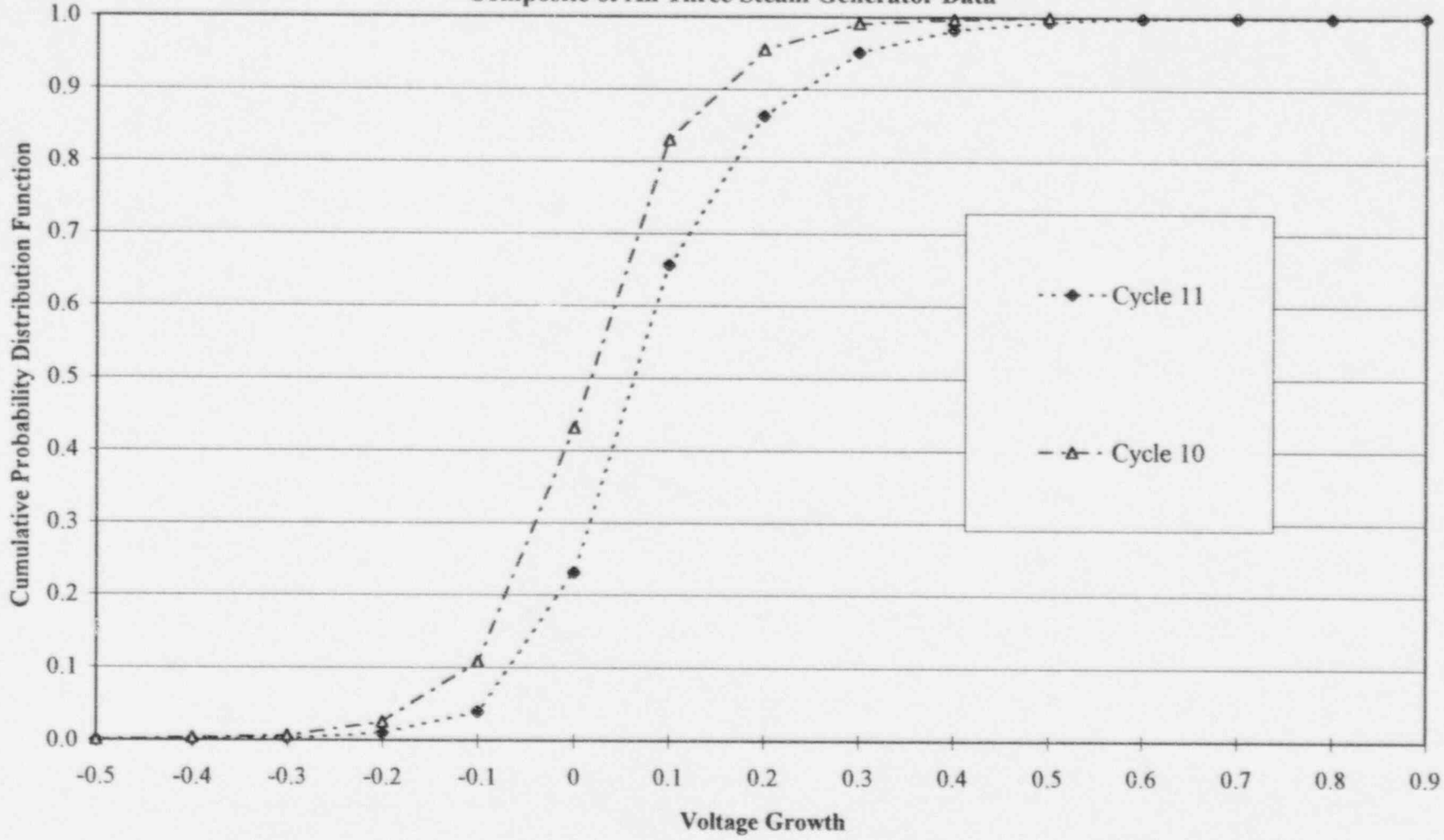


Figure 3 - 8
Beaver Valley Unit -1 Cycle 11 (1995 to 1996)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

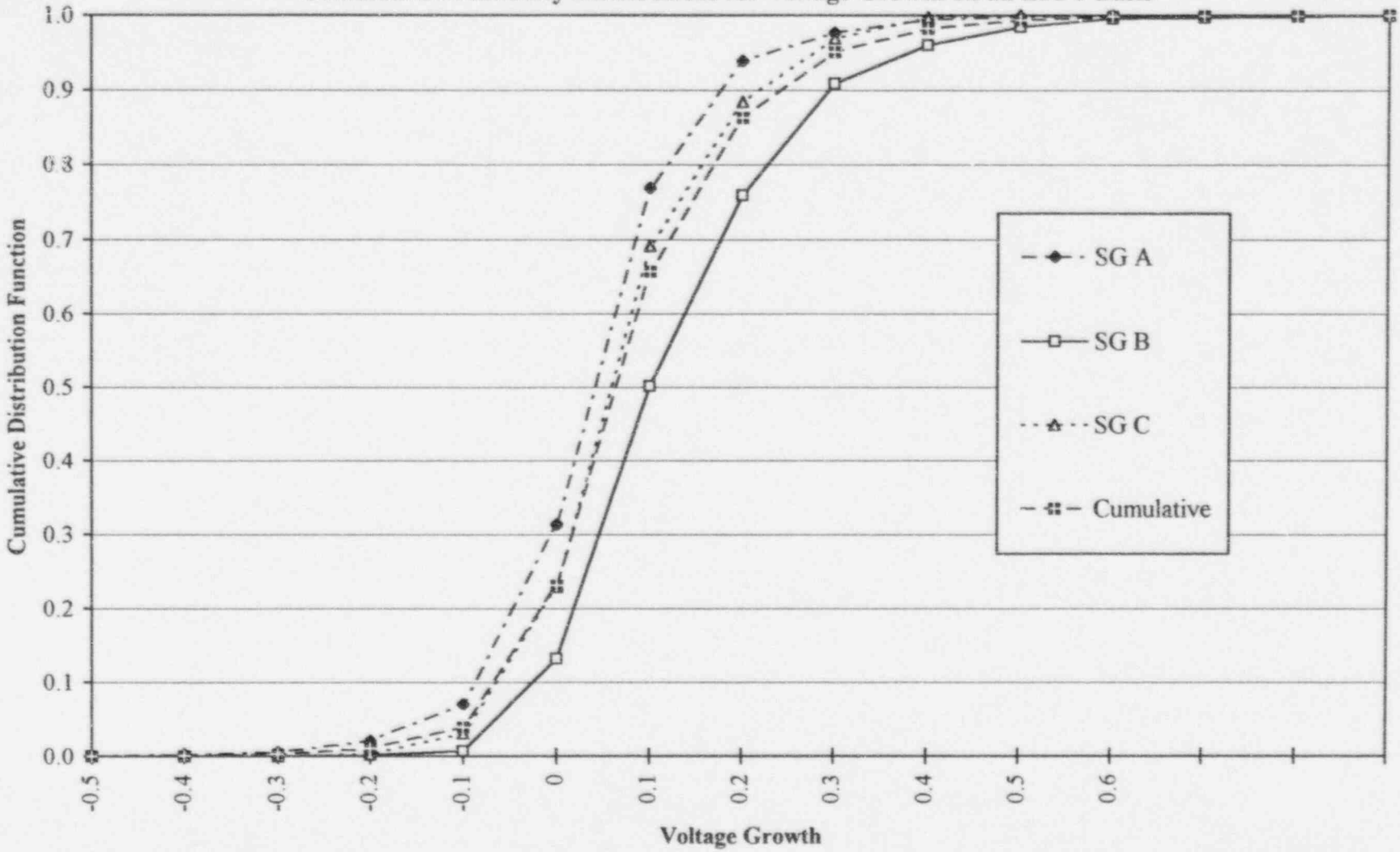
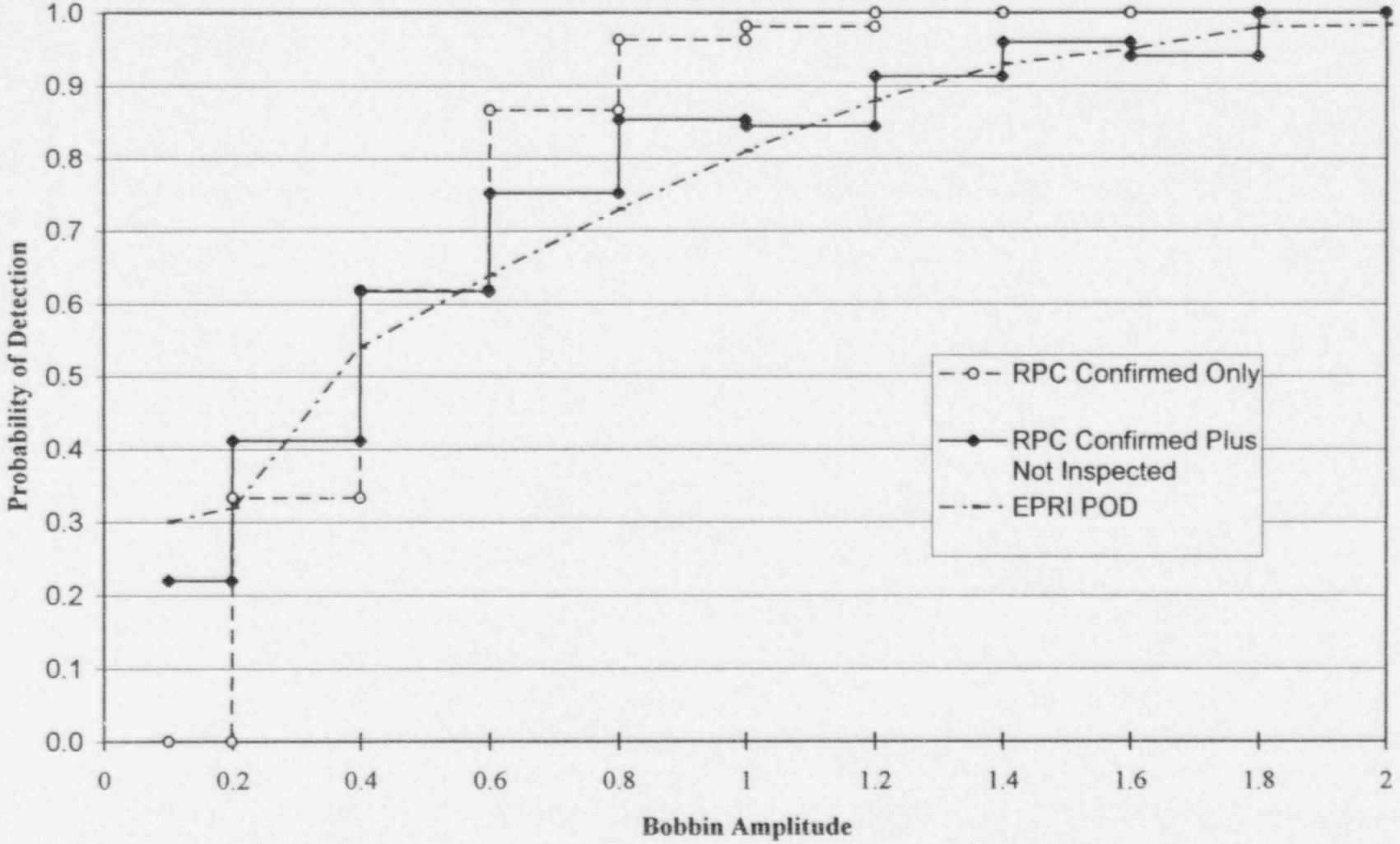


Figure 3-9
Beaver Valley Unit - 1
1996 EOC-11 Evaluation for POPCD at EOC-10



4.0 DATA BASE APPLIED FOR ARC CORRELATIONS

The database used for the ARC correlations that are applied in the analyses of this report are consistent with the NRC SER applicable to the Beaver Valley Unit 1 EOC-11 inspection (Reference 9.3). The SER recommended data for the burst pressure correlation is the same as the EPRI recommended database as noted in Reference 9.2. Per NRC requests, this database has been updated to include more recent pulled tube data from Plants A-1, A-2 and W-1 as well as the Beaver Valley Unit-1 pulled tube data from the EOC-10 inspection.

For the SLB leak rate correlation, the NRC recommends that Model Boiler specimen 542-4 and Plant J-1 pulled tube R8C74, TSP1 be included in the database. This database is referred to as the NRC database and is applied for the leak rate analyses of this report. The probability of leakage correlation of Reference 9.2 is also accepted by the NRC SER and applied in this report. The SLB leak rate data do not satisfy the NRC guidelines for a voltage dependent correlation, as discussed in Section 5.0.

Correlations have been developed for the evaluation of ODSCC indications at TSP locations in steam generators of nuclear power plants which relate bobbin voltage amplitudes, free span burst pressure, probability of leakage and associated leak rates. The Westinghouse methodology used in the calculation of these parameters, documented in References 9.2 and 9.5, is consistent with NRC criteria and guidelines of References 9.1 and 9.3.

The analysis process starts with the receipt of bobbin voltage from the site ECT inspection team. The site data consists of electronic files which include Row, Column, TSP identification number, and bobbin voltage. This data, sorted by bobbin voltage into "voltage bins" consisting of number of indications in discrete voltage ranges in increments of 0.1 volt, constitutes one major component of input for the subsequent voltage distribution, leak and burst probability calculations. It is noted that reference to "volts" in this report invariably applies to "voltage bins", when cited to one significant figure after the decimal (e.g., 1.8 volts). The true value of an indication would be cited to two significant figures after the decimal (e.g., 1.71 volts).

The calculation consists of determining the initial conditions (i.e., the bobbin indication population distribution), projecting the indication growth over the operating period, and then evaluating the tube leak and burst probabilities at the end of the operating period. Since indication growth is considered proportional to operating time, the limiting tube conditions occur at the end of any given time period or cycle.

5.0 SLB ANALYSIS METHODS

Monte Carlo analyses are used to predict the EOC-12 voltage distributions and to calculate the SLB leak rates and tube burst probabilities for both the actual EOC-11 voltage distribution and the predicted EOC-12 voltage distribution. These methods are consistent with the requirements of the Beaver Valley Unit-1 NRC SER and are described in the generic methods report of WCAP-14277 (Reference 9.5) and the prior reports for Beaver Valley Unit-1 (References 9.2 and 9.4), and are in accord with NRC Generic Letter 95-05.

The NRC SER recommended leak rate database does not satisfy the requirement for applying the SLB leak rate versus bobbin voltage correlation. The NRC requirement is that the p value obtained from the regression for the slope parameter be less than or equal to 5%. For the NRC recommended data, the p value is about 6.5% and the leak rate versus voltage correlation is not applied. Licensing-basis analyses were carried out using a SLB leak rate correlation based on an average of all leak rate data independent of voltage. The analysis methods for applying this leak rate model are given in Section 4.6 of WCAP-14277 (Reference 9.5). Since application of leak data independent of voltage yields very conservative results, sensitivity analyses using leak rate data correlated to voltage were also performed to demonstrate the degree of conservatism in the calculated SLB leak rates. A Monte Carlo analysis is applied to account for parameter uncertainties even though the leak rate is independent of voltage. This method of leak rate analysis is similar to that of draft NUREG-1477 except for the uncertainty treatment.

6.0 BOBBIN VOLTAGE DISTRIBUTIONS

6.1 PROBABILITY OF DETECTION (POD)

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

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

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 during the previous cycle) reported in the current inspection.

POD = Probability of Detection.

N_{repaired} = Number of N_i which are repaired (plugged) after the last cycle.

$N_{\text{deplugged}}$ = Number of previously-plugged indications which are deplugged after the last cycle and are returned to service.

The NRC generic letter (Reference 9.1) requires the application of a POD = 0.6 to define the BOC distribution for the EOC voltage projections, unless an alternate POD is approved by the NRC.

6.2 CYCLE OPERATING TIME

The operating periods used in the voltage projection calculations are:

Cycle 10 = 435.79 EFPD

Cycle 11 = 325.94 EFPD

Cycle 12 = 425. EFPD

6.3 CALCULATION OF VOLTAGE DISTRIBUTIONS

Bobbin voltage projections start with a cycle initial voltage distribution which is projected to the corresponding cycle final voltage distribution, based on the growth rate adjusted for the anticipated cycle operating time period. The overall growth rates for each of the Beaver Valley Unit 1 steam generators during the previous two operating periods, as represented by their cumulative probability distribution functions, are shown on Figure 3-7. The 1995 - 1996 operation (Cycle 11) growth rates exceed those of the 1993 - 1995 (Cycle 10) operation and are used to predict the EOC-12 bobbin voltage distributions. Further conservatism for the EOC-12 bobbin voltage prediction is provided by the use of the larger of the composite growth rate for all SGs and the SG-specific growth rate in projecting EOC voltages each SG. The methodology used in the calculations of EOC bobbin voltage distributions is described in Reference 9.5.

For each SG, the initial bobbin voltage distribution of indications being returned to service for the next cycle (BOC-12) is derived from the actual EOC-11 inspection results adjusted for tubes that are either (a) taken out of service by plugging, or (b) have been recovered for Cycle 12 service by deplugging of tubes plugged in previous outages based on prior repair criteria. The Cycle 12 bobbin voltage population, summarized on Table 6-1, shows EOC-11 bobbin voltage indications; the subsequent plugged indications (which were in service for Cycle 11 and then taken out of service, albeit not all for reasons of ODSCC at TSP); those indications recovered for service from previously plugged tubes, which were deplugged during this outage and were inspected and returned to service in accordance with ARC criteria (otherwise they were replugged); and also shows the BOC-12 indications corresponding to a constant POD value of 0.6.

As mentioned in Section 3.4, the NRC SER (Reference 9.3) 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. The fraction that can be applied for 1995 RPC NDD indications is 0.7 and it is used in the calculation of the BOC-12 indication distribution shown in Table 6-1.

6.4 PREDICTED EOC-12 VOLTAGE DISTRIBUTIONS

The licensing-basis calculation for the predicted EOC-12 bobbin voltage distributions is performed for all SGs with a constant POD value of 0.6 in accordance with NRC direction. However, for the limiting SG (SG B) calculations were also performed using a voltage dependent POD distribution developed based on bobbin and RPC data from 11 eddy current inspections at 8 different plants. This voltage dependent POD distribution is described here (Section 8.0) and is discussed in a greater detail in Reference 9.6.

The NRC SER (Reference 9.3) allows for consideration of only a fraction of RPC NDD indications from the current inspection in establishing BOC voltage distribution for the next cycle. Based on the data presented in Section 3.4 and NRC directives in Reference 9.3, the fractional value applicable for EOC-12 analysis is 0.7. Thus, only 70% of the 1995 RPC NDD indication population was included in the BOC-12 voltage distributions shown in Table 6-1.

Using the methodology previously described, analyses were performed to predict the performance of the Beaver Valley Unit-1 steam generators at EOC-12, based on the BOC-12 voltage distribution shown in Table 6-1. As mentioned earlier, the EOC-11 composite growth rate data shown in Table 3-6 were applied to SGs A and C (since their own growth rates are smaller than the composite growth rate) whereas its own growth rate distribution was used for SG B (since it is higher than the composite growth rate). This approach is recommended in Reference 9.5. The EOC-12 voltage distributions projected using the BOC-12 ARC voltage distribution shown in Table 6-1 are summarized in Table 6-2. As anticipated, the largest number of indications is predicted for SG A, 1513.5 indications predicted for POD = 0.6. For each steam generator, the assumed BOC-12 and the EOC-12 predicted bobbin voltage frequency distributions are shown on Figure 6-1 for all three SGs. The maximum bobbin voltage predicted for EOC-12 is 3.7 volts for POD = 0.6, in SG B.

6.5 COMPARISON OF PREDICTED AND ACTUAL EOC-11 VOLTAGE DISTRIBUTIONS

The actual EOC-11 bobbin voltage distributions and the corresponding predictions, summarized on Table 6-3 and shown on Figure 6-2, provide a comparison of the EOC-11 voltage distributions. SG A was predicted to be limiting for EOC-11 which is consistent with the actual measurement since the highest number of indications were detected in it. Also, as predicted, the largest indication was found in SG B, but the

predicted voltage value is slightly below the measurement (3.1 volts vs. 3.4 volts). Total number of indications were under predicted for SG-C.

As shown on Figure 6-2, calculations based on a constant POD value of 0.6 overpredicted the actual EOC-11 bobbin voltage population for voltage bins over 0.8 volts for all SGs, while underpredicting the population for voltages below 0.7 volt. The overprediction in the higher volt range demonstrates the conservatism in the growth rate distribution used for the prediction. The predicted peak bobbin voltages of 3.0 volts and 2.3 volts for SGs A and C, respectively, are conservative relative to the corresponding actual measured bobbin voltage indication of 2.2 volts and 1.8 volts.

Table 6-1
Beaver Valley Unit - 1 April 1996
Summary of Inspection and Repair During EOC - 11 Outage

	Steam Generator A				Steam Generator B				Steam Generator C			
	EOC-11 MEASURED			BOC-12 # DISTRIBUTION	EOC-11 MEASURED			BOC-12 # DISTRIBUTION	EOC-11 MEASURED			BOC-12 # DISTRIBUTION
Delta Volt Bin	In Service All Inds.	Deplugged Tubes Only	Plugged Tubes Only	POD=.6	In Service All Inds.	Deplugged Tubes Only	Plugged Tubes Only	POD=.6	In Service All Inds.	Deplugged Tubes Only	Plugged Tubes Only	POD=.6
0.2	4	0	0	6.67	13	1	1	21.67	3	1	0	6.00
0.3	49	2	1	82.17	34	1	2	54.67	24	10	0	50.00
0.4	102	3	1	172.00	64	1	6	100.67	47	14	0	92.33
0.5	122	8	4	206.33	92	4	3	154.33	51	14	2	97.00
0.6	130	8	4	220.17	90	5	4	150.50	62	20	1	122.33
0.7	116	8	5	196.33	90	10	9	151.00	59	22	1	116.33
0.8	88	9	3	151.67	80	9	7	135.33	45	23	0	95.50
0.9	76	13	3	135.67	67	7	3	115.67	37	20	2	79.17
1.0	66	11	1	120.00	55	7	5	93.67	23	19	1	64.17
1.1	41	6	3	71.33	41	12	2	78.33	15	21	0	44.50
1.2	26	9	2	49.33	21	15	1	49.00	8	19	0	32.33
1.3	10	11	0	27.67	20	10	1	41.83	4	12	0	18.67
1.4	7	13	1	23.67	11	10	1	27.33	4	16	0	22.67
1.5	2	5	0	8.33	9	5	0	19.50	0	11	0	11.00
1.6	2	10	0	13.33	4	11	1	16.67	1	10	0	11.67
1.7	4	7	0	13.67	4	5	0	11.67	0	7	0	7.00
1.8	1	5	0	6.67	1	2	0	3.67	1	8	0	9.67
1.9	1	4	0	5.67	1	5	0	6.67	0	3	0	3.00
2.0	0	1	0	1.00	0	2	0	2.00	0	1	0	1.00
2.1	1	0	1	0.67	0	1	0	1.00	0	0	0	0.00
2.2	0	0	0	0.00	0	0	0	0.00	0	1	0	1.00
2.3	1	0	0	1.17	0	0	0	0.00	0	0	0	0.00
3.4	0	0	0	0.00	1	0	1	0.67	0	0	0	0.00
Total	849	133	29	1513.50	698	123	47	1235.83	389	252	7	885.33
> 1V	96	71	7	151.17	113	78	7	258.33	33	109	0	226.67
> 2V	2	0	1	1.83	1	1	1	1.67	0	1	0	1.00

Only 70 % of RPC NDD indications are included in establishing the BOC-12 indication population.

Table 6 - 2
Beaver Valley Unit-1 April 1996
Voltage Distribution Projection for EOC - 12

Voltage Bin	Steam Generator A	Steam Generator B	Steam Generator C
	Projected Indications Distributions at EOC -12 , POD = 0.6		
0.1	0.08	0.16	0.07
0.2	4.74	6.68	3.62
0.3	38.73	22.88	23.63
0.4	96.80	50.63	53.37
0.5	149.47	86.03	77.51
0.6	181.66	114.88	96.28
0.7	188.64	131.61	104.88
0.8	176.45	135.82	101.71
0.9	156.36	129.58	91.26
1.0	132.49	116.75	77.29
1.1	106.03	100.34	62.32
1.2	80.22	82.66	48.36
1.3	58.13	65.81	36.79
1.4	41.12	51.07	27.87
1.5	29.06	38.91	21.19
1.6	20.92	29.26	16.25
1.7	15.35	21.70	12.45
1.8	11.38	15.86	9.43
1.9	8.35	11.41	6.96
2.0	5.96	7.99	4.96
2.1	4.13	5.48	3.40
2.2	2.77	3.66	2.24
2.3	1.79	2.37	1.43
2.4	1.14	1.49	0.88
2.5	0.71	0.91	0.21
2.6	0.04	0.54	0.70
2.7	0.70	0.32	0.00
2.8	0.00	0.05	0.30
2.9	0.30	0.00	0
3.0	0	0.00	0
3.1	0	0.70	0
3.2	0	0.00	0
3.3	0	0.00	0
3.4	0	0.00	0
3.5	0	0.00	0
3.6	0	0.00	0
3.7	0	0.30	0
Total	1513.50	1235.83	885.33

Table 6 - 3
Beaver Valley Unit-1 April 1996
Comparison of Predicted and Actual EOC-11 Voltage Distributions

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C	
	EOC-11 Prediction	EOC-11 Actual	EOC-11 Prediction	EOC-11 Actual	EOC-11 Prediction	EOC-11 Actual
	POD=.6 No. of Indications	No. of Indications	POD=.6 No. of Indications	No. of Indications	POD=.6 No. of Indications	No. of Indications
0.1	0.05	0	0.11	0	0.00	0
0.2	2.47	4	4.63	13	0.34	3
0.3	19.55	49	23.51	34	5.43	24
0.4	49.86	102	48.57	64	16.43	47
0.5	81.37	122	78.03	92	31.88	51
0.6	101.56	130	91.15	90	41.52	62
0.7	110.99	116	93.12	90	44.68	59
0.8	109.14	88	91.27	80	43.61	45
0.9	96.91	76	83.32	67	40.25	37
1.0	79.13	66	68.49	55	34.04	28
1.1	59.75	41	51.14	41	25.68	15
1.2	42.52	26	35.50	21	17.57	8
1.3	29.54	10	23.73	20	11.41	4
1.4	20.58	7	15.62	11	7.27	4
1.5	14.64	2	10.17	9	4.69	0
1.6	10.68	2	6.53	4	3.03	1
1.7	7.94	4	4.15	4	1.92	0
1.8	5.95	1	2.61	1	1.19	1
1.9	4.42	1	1.63	1	0.73	0
2.0	3.23	1	1.00	0	0.01	0
2.1	2.30	0	0.62	0	0.70	0
2.2	1.61	[illegible]	0.38	0	0.00	0
2.3	1.10	[illegible]	0.25	0	0.30	0
2.4	0.74	0	0.16	0	0	0
2.5	0.50	0	0.00	0	0	0
2.6	0.15	0	0.00	0	0	0
2.7	0.00	0	0.70	0	0	0
2.8	0.70	0	0.00	0	0	0
2.9	0.00	0	0.00	0	0	0
3.0	0.30	0	0.00	0	0	0
3.1	0	0	0.30	0	0	0
3.4	0	0	0	1	0	0
TOTAL	857.67	849	736.67	698	332.67	389
> 1.0 V	206.65	96	154.47	113	74.48	33
> 2 V	7	1	2.40	1	1	0

Figure 6-1
Beaver Valley Unit-1 April 1996
Comparison of BOC-12 Bobbin Voltage Distributions with Predicted EOC-12 Distributions

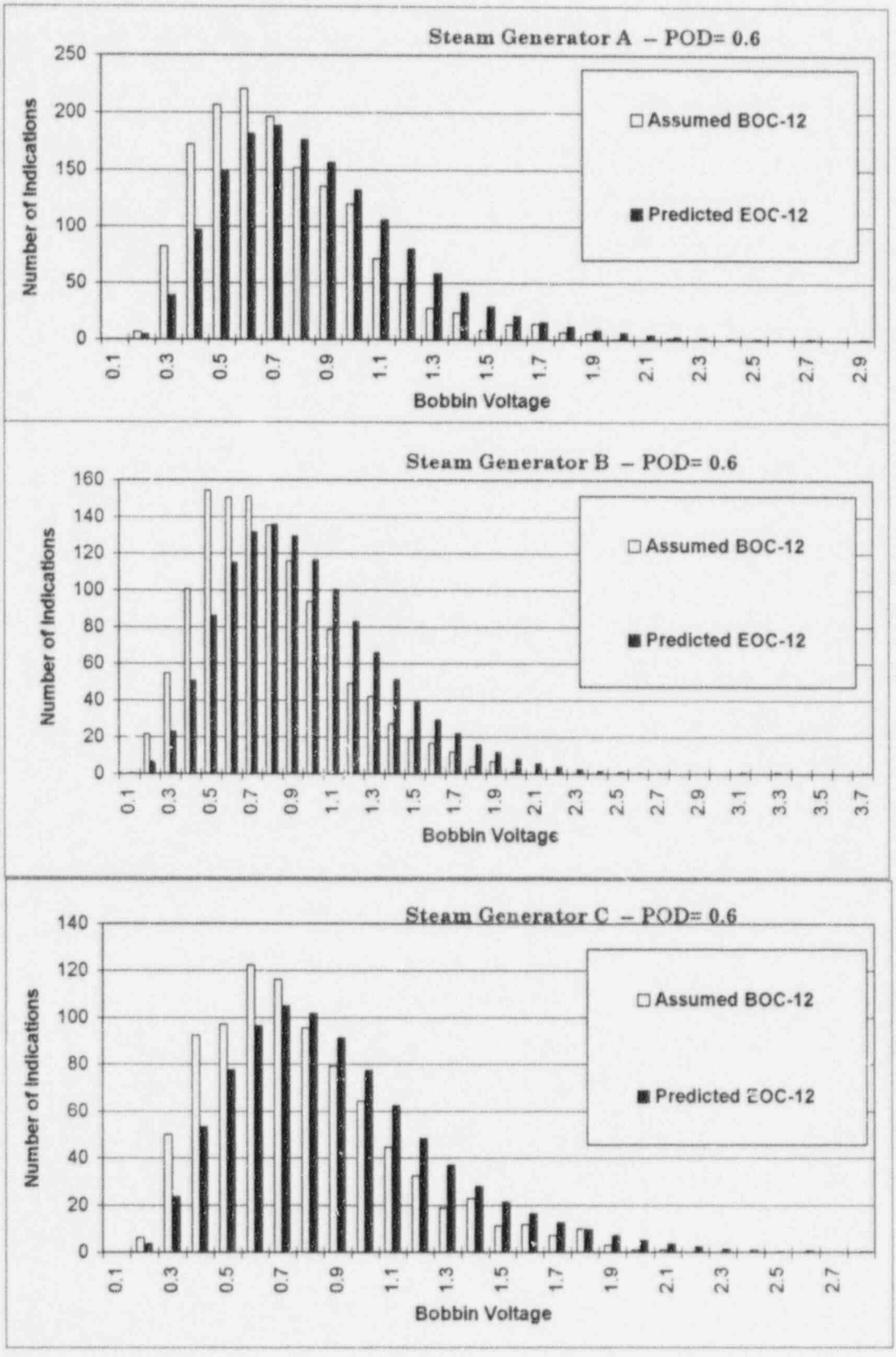
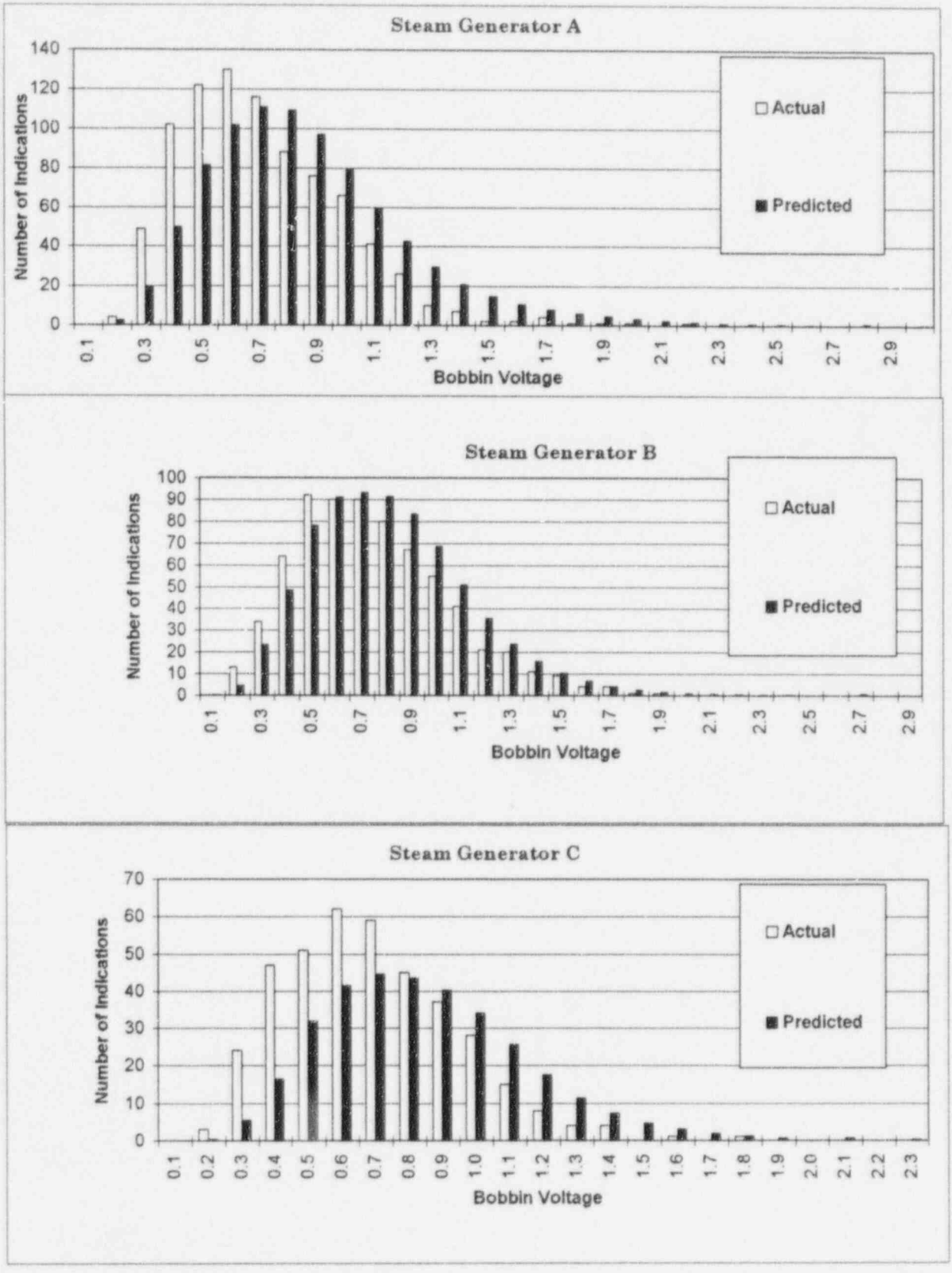


Figure 6-2
Beaver Valley Unit-1 April 1996
Comparison of Predicted EOC-11 Bobbin Voltage Distributions with Actual Measured Distributions



7.0 TUBE LEAK RATE AND TUBE BURST PROBABILITIES

7.1 CALCULATION OF LEAK RATE AND TUBE BURST PROBABILITIES

Correlations have been developed for the evaluation of ODSCC indications at TSP locations in steam generators of nuclear power plants which relate bobbin voltage amplitudes (either measured or calculated), free span burst pressure, probability of leakage and associated leak rates. The Westinghouse methodology used in the calculation of these parameters, documented in References 9.2 and 9.5, is consistent with NRC criteria and guidelines of References 9.1 and 9.3.

7.2 PREDICTED AND ACTUAL LEAK RATE AND TUBE BURST PROBABILITY FOR EOC-11

Using the methodology previously described, analyses were performed to calculate EOC-11 SLB tube leak rate and probability of burst for the actual bobbin voltage distribution at EOC-11 (with no growth projection applied) previously presented in this report. The results of Monte Carlo calculations performed for the actual voltage distributions are compared to the predictions based on the EOC-10 data, as shown on Table 7-1. To ensure meaningfulness of this data comparison, projections for EOC-11 conditions were repeated for all three SGs using the same Monte Carlo code used for the calculations with the actual voltage data. This assures that the database and methods used for EOC-11 projections are consistent with those applied for the actual EOC-11 analyses.

In reviewing the present EOC-11 projection results it was found that Table 8-2 of Reference 9.2 reported that a 95% confidence limit on the predicted total leak rate in SG A during a postulated SLB event at the EOC-11 would be on the order of 0.31 gpm while the present prediction yields 2.37 gpm. An investigation of the differences revealed that an error had been made in the prior calculation in that the variability of the leak rate had not been properly included in the analysis. In essence, the previously reported value corresponds more to an expected average leak rate than a 95% confidence value. The distribution of indications in SG A was reanalyzed with the result that the 95% confidence value for the total leak rate during a postulated SLB event would be expected to be 2.37 gpm.

A comparison of the EOC-11 actuals with the corresponding projections indicates the following:

a) Actual ECT bobbin measurements at EOC-11 confirm the prediction of largest indication at EOC-11 in SG B, but the projected peak voltage is below that actually measured (3.4 volts measured vs. 3.1 volts projected).

b) SG A was predicted to be the most limiting steam generator for Cycle 11 from the standpoint of SLB leak rate and tube burst probability (although SG B was predicted to have the largest indication at EOC-11).

c) The same EOC-11 SLB leak rate value (1.50 gpm) was predicted with actual measured voltage distributions for SGs A and B and it is below the leak rates projected for those two SGs. The SLB leak rate calculated from the actual EOC-11 voltage distributions for all three SGs are well below the Beaver Valley Unit-1 allowable limit of 4.5 gpm (Reference 9-3)

d) The tube burst probabilities calculated from actual EOC-11 voltage distributions for SGs A and B are slightly above the values projected for them, but the absolute magnitudes are very small, and all calculated burst pressures are well below the NRC reporting threshold of 1×10^{-2}.

7.3 PROJECTED LEAK RATE AND TUBE BURST PROBABILITY FOR EOC-12

Using the methodology previously described, calculations have been conducted to predict the performance of all three steam generators in Beaver Valley Unit-1, and the results are summarized in Table 7-2. EOC-12 bobbin voltage distributions as well as leak rates and tube burst probabilities based on those distributions are predicted. Two sets of results are shown in Table 7-2: 1) one set of results for all three SGs based on the present licensing-basis database and method, and 2) another set from more realistic analyses for the limiting SG, which is SG B.

Results based on the present licensing-basis database and method for all three SGs meet the ARC acceptance for Beaver Valley Unit-1. The predicted EOC-12 SLB leak rate for SG B is calculated to be at the Beaver Valley Unit 1 allowable SLB limit of 4.50 gpm[1] (Reference 9-5), whereas SG A yields 4.28 gpm. However, as discussed in the following paragraphs, the leak rate results based on the present licensing-basis database and method are very conservative and, therefore, the true margin to the acceptance limit for SG B is expected to be significantly higher. The EOC-12 SLB tube

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[1] The number of simulations in the Monte Carlo analysis for SG B was increased to 1 million (from 250,000 simulations used normally) to estimate projected leak rate to two decimal digit accuracy.

burst probability for all three SGs are well below the NRC reporting guideline for tube burst probability of 1.0×10^{-2} .

To demonstrate conservatism in the leak rate results based on the present licensing-basis database and method, two other calculations were performed for the limiting SG (SG B) using an ARC updated database and one additional calculation using the present licensing database but a more realistic method of accounting for leak rate data uncertainties in Monte Carlo simulations as explained below. As discussed in Section 5.0, the present NRC recommended database for leak rates for 7/8 inch diameter tubes does not meet the requirement for correlating leak rate to bobbin voltage and, therefore, leak rate calculations assume that leak rate data are independent of voltage. However, parameter uncertainties are considered in the projections using Monte Carlo methods of Reference 9.5 which assumes a conservative log-normal distribution for leak rate. The method used presently to estimate non-log leak parameters from the log leak rate distribution is known to be biased towards overestimating the leak rate actually used in the Monte Carlo simulations. Therefore, an alternate method that yields unbiased, best estimates for leak rates from the sample data of log leak rates was also used to project EOC-12 leak rate for the limiting SG (SG B). As shown in Table 7-2, the use of best estimate non-log leak rate parameters in the Monte Carlo simulations reduces the EOC-12 SLB leak rate projection for SG B by 20 percent to 3.58 gpm. Thus, even with the present NRC-approved database and methodology, the margin in the projected EOC-12 SLB leak rate for SG B can be increased significantly by eliminating undue conservatism in establishing non-log leak rate parameters from log rate distribution parameters.

The reason for the current 7/8 inch tube leak rate database not satisfying the requirement for applying the SLB leak rate versus bobbin voltage correlation is inclusion of leak and burst data from the French plants. A detailed evaluation presented in Reference 9.6 that includes all available French data shows that they do not behave as they are from the same population as the data from the U. S. plants and, thus, it is justifiable to exclude them from the ARC database. With the French data removed, the requirement for applying the SLB leak rate versus bobbin voltage correlation can be met, and Reference 9.6 presents the distribution parameters for such correlations for leak rate as well as burst probability. As shown in Table 7-2, SLB leak rate calculated with that leak rate versus bobbin voltage correlation is 1/9th of that predicted with the present NRC database. Thus, there is substantial margin in the predicted SLB leak rates for all SGs, including SG B. Once Reference 9.6 (which excludes the French Data) is accepted by the NRC, Duquesne Lights' intention is to use the updated database in its EOC calculations. The new predicted EOC-12 SLB tube leak rate for SG B is calculated to be 0.52 gpm.

Yet another source of conservatism in the present methodology is application of a constant POD value for the entire bobbin voltage range. Sufficient database now exists to define an alternate POD that is dependent on the bobbin voltage, and the development of such a POD is discussed in Section 8. Bobbin and RPC data from 11 inspections at 8 different plants have been analyzed to establish a voltage dependent POD termed as POPCD. As the results in Table 7-2 indicate, the use of this voltage dependent POD results in a further 20 percent reduction in leak rates and about a 16 percent reduction in tube burst probability for SG B.

In summary, the EOC-12 SLB leak rates and tube burst probabilities calculated for all three SGs using the present NRC-approved database and method meet the SER limits for Beaver Valley Unit-1. Results based on an updated database show that the margin between the EOC-12 predictions and acceptance limits can be increased substantially.

Table 7-1
Beaver Valley Unit 1 1996 EOC- 11 Outage
Summary of Calculations of Tube Leak Rate and Burst Probability
Based on Actual Bobbin Voltage - 250k Simulations

Steam Generator	POD	Number of Indications	Max. Volts[1]	Burst Probability		SLB Leak Rate gpm
				1 Tube	2 Tubes	
EOC - 11 PROJECTIONS [2]						
A	0.6	857.7	3.0	5.50×10^{-5}	$< 3.3\times10^{-6}$	2.37
B	0.6	736.7	3.1	5.42×10^{-5}	$< 3.3\times10^{-6}$	1.76
C	0.6	332.7	2.3	1.16×10^{-5}	$< 3.3\times10^{-6}$	0.76
EOC - 11 ACTUAL						
A	1	849	2.6	6.07×10^{-5}	$< 3.3\times10^{-6}$	1.50
B	1	698	3.7	6.48×10^{-5}	$< 3.3\times10^{-6}$	1.50
C	1	389	2.1	$< 3.3\times10^{-6}$	$< 3.3\times10^{-6}$	0.57

Notes:
(1) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
(2) Projection analyses were repeated using the same Monte Carlo code used for the analysis based on the actual voltages.

Table 7-2
Beaver Valley Unit 1 1996 EOC- 11 Outage
Projections of Tube Leak Rate and Burst Probability for EOC-12
Based on Actual Bobbin Voltage - 250k Simulations

Steam Generator	POD	Number of Indications	Max. Volts[1]	Burst Probability		SLB Leak Rate gpm
				1 Tube	2 Tubes	
EOC - 12 PROJECTIONS -- Present Licensing Basis Calculations						
A	0.6	1513.5	2.9	1.23×10^{-4}	$< 4\times10^{-6}$	4.28
B	0.6	1235.8	3.7	1.76×10^{-4}	$< 4\times10^{-6}$	4.50[2]
C	0.6	885.3	2.8	1.02×10^{-4}	$< 4\times10^{-6}$	2.76
EOC - 12 PROJECTIONS -- Realistic Calculations for the Limiting SG (SG B)						
Unbiased Non-Log Parameter	0.6	1235.8	3.7	1.22×10^{-4}	$< 4\times10^{-6}$	3.58
Leak Rate Correlated to Volts	0.6	1235.8	3.7	1.51×10^{-4}	$< 4\times10^{-6}$	0.52
Leak Rate Correlated to Volts	POPCD	1091.4	2.9	1.26×10^{-4}	$< 4\times10^{-6}$	0.40

Notes:
(1) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
(2) Based on a Monte Carlo analysis with 1 million simulations.

8.0 COMPARISON OF PROBABILITY OF PRIOR CYCLE DETECTION FOR 15 INSPECTIONS, 8 PLANTS WITH EPRI POD

The evaluation of the POPCD for Beaver Valley Unit-1 is described in Section 3.4. At this time, POPCD evaluations are available for 15 inspections at eight plants, including two evaluations for Beaver Valley Unit-1. The available data include ten inspections of plants with 7/8" diameter tubing and five inspections of plants with 3/4" diameter tubing. This section summarizes these POPCD evaluations for comparison with the EPRI proposed POD. The POPCD evaluations performed since 1992 show significant improvement over the earlier assessments which represent the first ARC inspections. Bobbin data analysis guidelines (Appendix A guidelines) have been revised since the first inspections to reflect the initial ARC experience. Thus, it is appropriate to assess POPCD for inspections performed since 1992. Eleven of the fifteen inspections for which POPCD has been evaluated were performed since 1992.

Table 8-1 shows the combined POPCD evaluation for plants with 7/8" diameter tubing and includes results for six inspections performed since 1992. These data are also plotted in Figure 8-1, and they include data from the present Beaver Valley Unit-1 assessment (EOC-10 results representing February 1995 inspection) as well as the data reported in Reference 9-2 for the EOC-9 inspection. The POPCD value approaches unity at about 3 volts, and the average value independent of voltage is about 0.67. The POPCD evaluation in Figure 8-1 is in good agreement with the EPRI POD except in the one to two volt range where POPCD is about 0.83 and the EPRI POD increases from about 0.82 to about 0.97.

Table 8-2 and Figure 8-2 show the combined POPCD evaluation for the five plants with 3/4" tubing and inspections performed since 1992. These results tend to support a POD approaching unity above about 3 volts. The POPCD assessment is in very good agreement with the EPRI POD. The average POPCD independent of voltage is about 0.64 which is in general agreement with the NRC Generic Letter 95-05 proposed voltage independent POD of 0.60.

The definition of POPCD includes indications which were not present at the prior inspection and thus could be expected to be somewhat lower than the EPRI POD which is based on "expert" evaluations of inspection results and does not include indications clearly below detectable levels.

The combined data for the eleven inspections since 1992 are given in Table 8-3 and the POPCD evaluation is shown in Figure 8-3 for RPC confirmed plus not inspected

The combined data for the eleven inspections since 1992 are given in Table 8-3 and the POPCD evaluation is shown in Figure 8-3 for RPC confirmed plus not inspected indications. It is seen that the inspections since 1992 yield a POPCD in good agreement with the EPRI POD which was a 1994 evaluation. POPCD supports a POD approaching unity at about 3.5 volts while the EPRI POD is about 0.98 at 2 volts and unity at 3 volts. Figure 8-3 also includes POPCD evaluated at the lower 95% confidence limit on the data for individual voltage bins

The POPCD evaluations shown in Figures 8-1 to 8-3 are based on the definition of "truth" as RPC confirmed plus not RPC inspected indications. Since many of the indications not RPC inspected would be expected to be found NDD if inspected, this represents a lower bound POPCD evaluation. Figure 8-4 shows the POPCD evaluation for all eleven inspections since 1992 based only on RPC confirmed indications. This results in a significant increase in POPCD below 1.0 volt and a modest increase above 1.0 volt. The data of Table 8-3 show 400 to 8600 indications in all voltage bins below 2 volts, more than 200 between 2.0 and 3.2 volts and about 5 indications above about 3.2 volts. Thus, the collective data provide a substantial database for defining a POD.

The results of Figure 8-3 clearly support an increase in the POD for ARC applications above the POD = 0.6, independent of voltage, required by NRC Generic Letter 95-05. For indications above 1.0 volt, the POD exceeds 0.9 and is 0.97 to near unity at 2.0 volts. A POD of 0.6 is only applicable to indications below about 0.6 volts.

An alternate, voltage dependent POD is developed as POPCD evaluated at the lower 95% confidence level and the mid-voltage of each voltage bin. The result is then smoothed to obtain the alternate POD as shown in Figure 8-5. The alternate POD is tabulated in Table 8-4 and compared with the EPRI POD in Figure 8-6. This POPCD distribution was used to perform an alternate EOC-12 projection for SG B as discussed in Section 7.3.

Table 8-1
Evaluation for POPCD for Plants with 7/8" SG Tubes
Combined Data from 6 Post-92 Inspections

Voltage Bin	New Indications		Bobbin Call in Both Inspections		First Inspection	POPCD			
	RPC Confirmed	RPC Confirmed plus not Inspected	RPC Confirmed	RPC Confirmed plus not Inspected	RPC Confirmed and Plugged	RPC Confirmed		RPC Confirmed Plus Not Inspected	
						Frac.	Count	Frac.	Count
>0 - 0.2	2	133	0	37	5	0.714	5 / 7	0.240	42 / 175
0.2 - 0.4	8	726	3	549	70	0.901	73 / 81	0.460	619 / 1345
0.4 - 0.6	12	797	10	1108	152	0.931	162 / 174	0.613	1260 / 2057
0.6 - 0.8	12	479	19	1160	124	0.923	143 / 155	0.728	1284 / 1763
0.8 - 1.0	10	231	24	792	72	0.906	96 / 106	0.789	864 / 1095
1.0 - 1.2	17	109	28	389	91	0.875	119 / 136	0.815	480 / 589
1.2 - 1.6	17	71	61	286	79	0.892	140 / 157	0.837	365 / 436
1.6 - 2.0	8	17	33	59	34	0.893	67 / 75	0.845	93 / 110
2.0 - 3.2	1	1	15	15	23	0.974	38 / 39	0.974	38 / 39
3.2 - 3.5	0	0	0	0	0	-	0 / 0	-	0 / 0
TOTAL	87	2564	193	4395	650				
Total > 1V	43	198	137	749	227				

Table 8-2
Evaluation for POPCD for Plants with 3/4" SG Tubes
Combined Data from 5 Post-92 Inspections

Voltage Bin	New Indications		Bobbin Call in Both Inspections		First Inspection	POPCD			
	RPC Confirmed	RPC Confirmed plus not Inspected	RPC Confirmed	RPC Confirmed plus not Inspected	RPC Confirmed and Plugged	RPC Confirmed		RPC Confirmed Plus Not Inspected	
						Frac.	Count	Frac.	Count
>0 - 0.2	8	1010	0	466	0	0	0 / 8	0.316	466 / 1476
0.2 - 0.4	95	3920	19	3154	31	0.345	50 / 145	0.448	3185 / 7105
0.4 - 0.6	103	2456	120	4064	86	0.667	206 / 309	0.628	4150 / 6606
0.6 - 0.8	85	918	267	2920	116	0.818	383 / 468	0.768	3036 / 3954
0.8 - 1.0	77	316	371	1701	114	0.863	485 / 562	0.852	1815 / 2131
1.0 - 1.2	46	90	91	456	883	0.955	974 / 1020	0.937	1339 / 1429
1.2 - 1.6	33	53	140	265	774	0.965	914 / 947	0.951	1039 / 1092
1.6 - 2.0	4	4	48	48	245	0.987	293 / 297	0.987	293 / 297
2.0 - 3.2	6	6	20	20	161	0.968	181 / 187	0.968	181 / 187
3.2 - 3.5	0	0	0	0	5	1.000	5 / 5	1.000	5 / 5
TOTAL	457	8773	1076	13093	2415				
Total > 1V	89	153	299	789	2068				

Table 8-3
Combined POPCD Evaluation for 11 post-92 Assessments
POPCD Based on RPC Confirmed Plus Not Inspected Indications

Voltage Bin	New Indications		Bobbin Call in Both Inspections		First Inspection	POPCD					
	RPC Confirmed	RPC Confirmed plus not Inspected	RPC Confirmed	RPC Confirmed plus not Inspected	RPC Confirmed and Plugged	RPC Confirmed			RPC Confirmed Plus Not Inspected		
						Frac.	Count	Lower 95% Limit	Frac.	Count	Lower 95% Limit
>0 - 0.2	10	1143	0	503	5	0.333	5 / 15	0.142	0.308	508 / 1651	0.289
0.2 - 0.4	103	4646	22	3703	101	0.544	123 / 226	0.487	0.450	3804 / 8450	0.441
0.4 - 0.6	115	3253	130	5172	238	0.762	368 / 483	0.728	0.624	5410 / 8663	0.616
0.6 - 0.8	97	1397	286	4080	240	0.844	526 / 623	0.818	0.756	4320 / 5717	0.746
0.8 - 1.0	87	547	395	2493	186	0.870	581 / 668	0.846	0.830	2679 / 3226	0.819
1.0 - 1.2	63	199	119	845	974	0.946	1093 / 1156	0.933	0.901	1819 / 2018	0.890
1.2 - 1.6	50	124	201	551	853	0.955	1054 / 1104	0.943	0.919	1404 / 1528	0.906
1.6 - 2.0	12	21	81	107	279	0.968	360 / 372	0.948	0.948	386 / 407	0.927
2.0 - 3.2	7	7	35	35	184	0.969	219 / 226	0.943	0.969	219 / 226	0.943
3.2 - 3.5	0	0	0	0	5	1.000	5 / 5	-	1.000	5 / 5	-
TOTAL	544	11337	1269	17489	3065						
Total > 1V	132	351	436	1538	2295						

Table 8-4
Comparison of Alternate POD
with EPRI POD

Voltage Bin	EPRI POD	Alternate POD
0.1	0.30	0.24
0.2	0.38	0.34
0.3	0.49	0.44
0.4	0.57	0.53
0.5	0.62	0.62
0.6	0.66	0.67
0.7	0.71	0.73
0.8	0.76	0.77
0.9	0.80	0.81
1	0.83	0.83
1.2	0.90	0.88
1.4	0.93	0.91
1.6	0.96	0.92
1.8	0.98	0.93
2	0.984	0.94
3	1.00	0.98
3.5	1.00	1.00

Figure 8-1
Combined POPCD Evaluation for 6 Post-92 Inspections for 7/8" Dia Plants
POPCD Based on RPC Confirmed Plus Not Inspected Indications

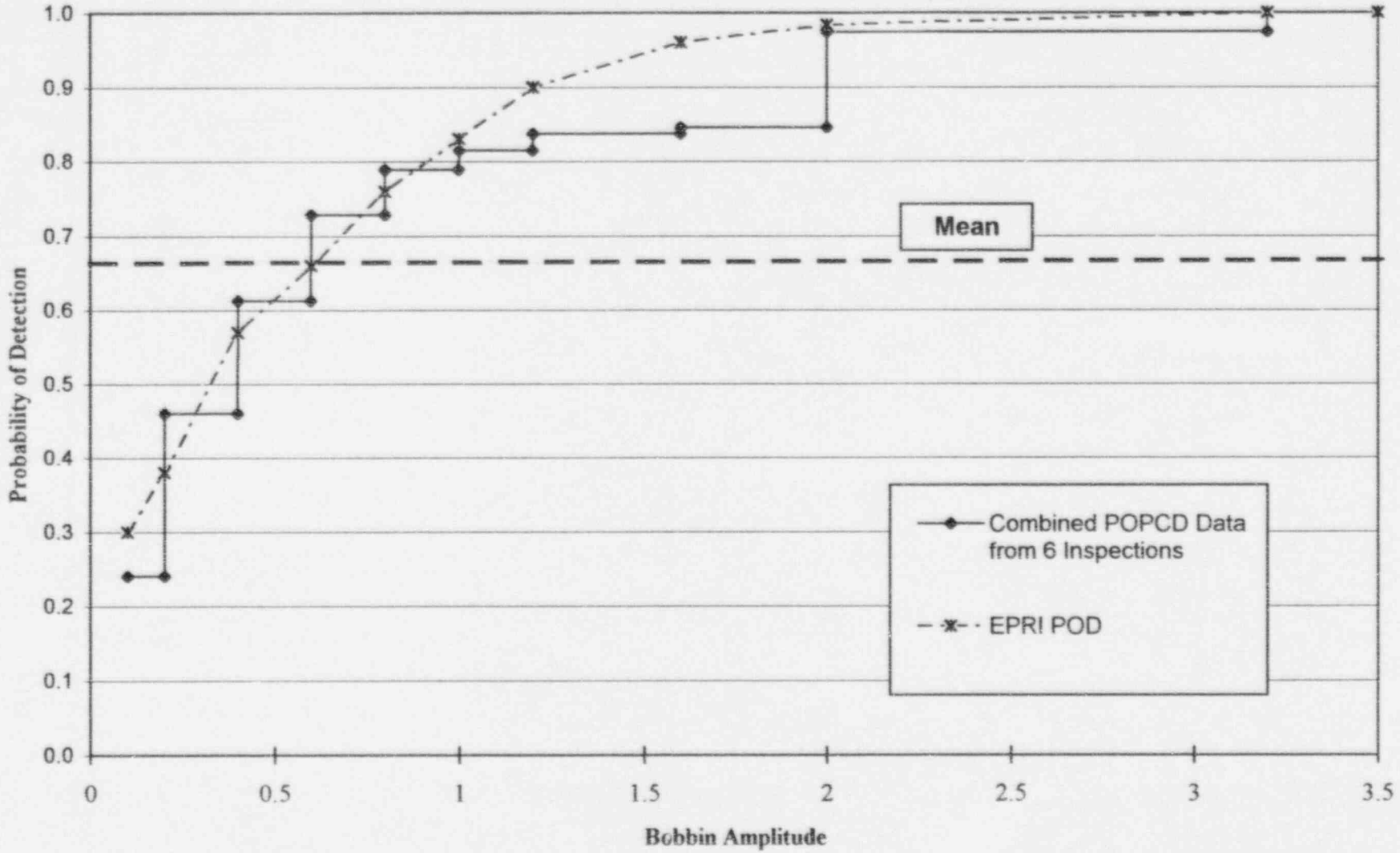


Figure 8-2
Combined POPCD Evaluation for 5 Post-92 Inspections for 3/4" Dia Plants
POPCD Based on RPC Confirmed Plus Not Inspected Indications

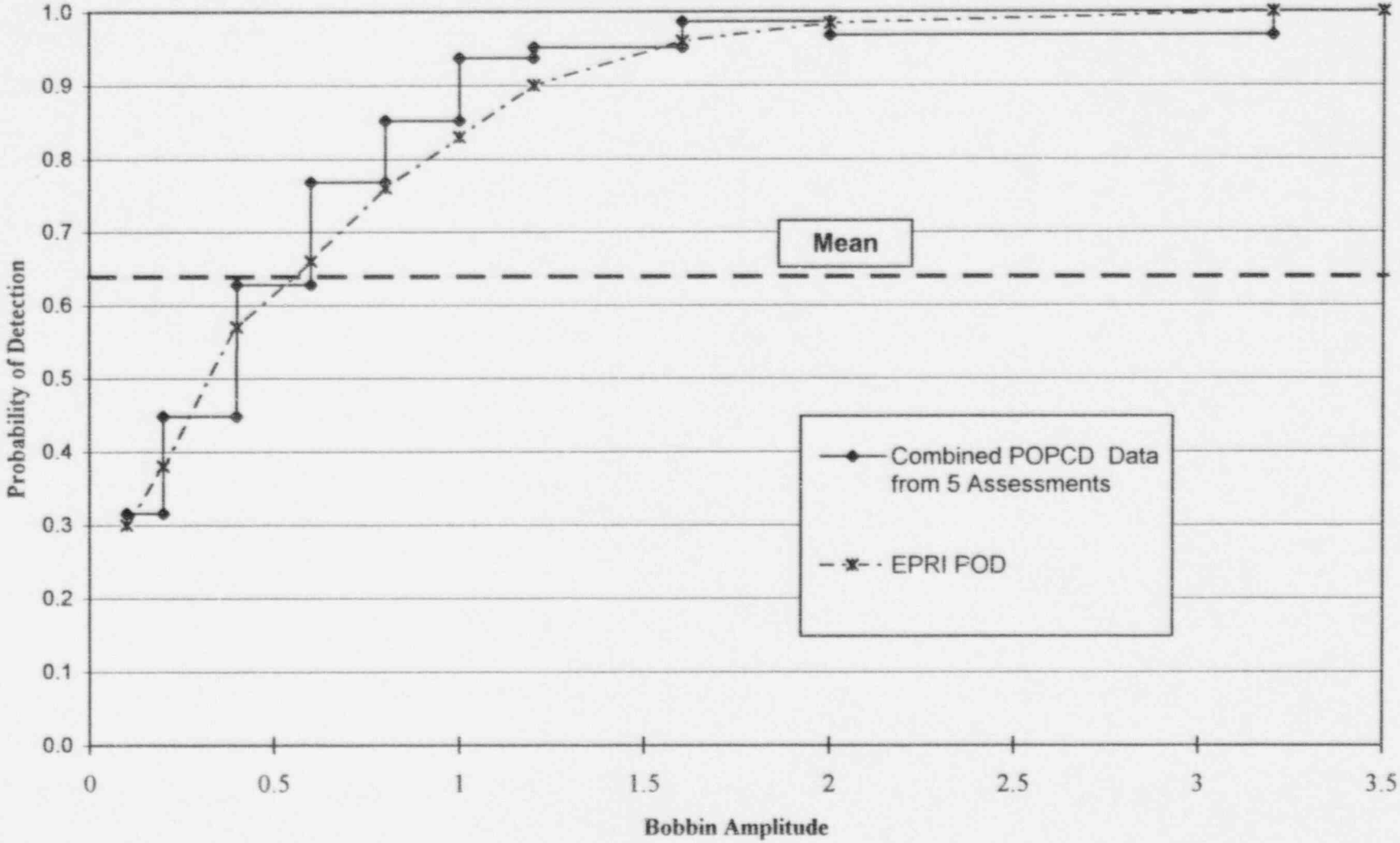


Figure 8-3
Combined POPCD Evaluation for 11 Post-92 Inspections
POPCD Based on RPC Confirmed Plus Not Inspected Indications

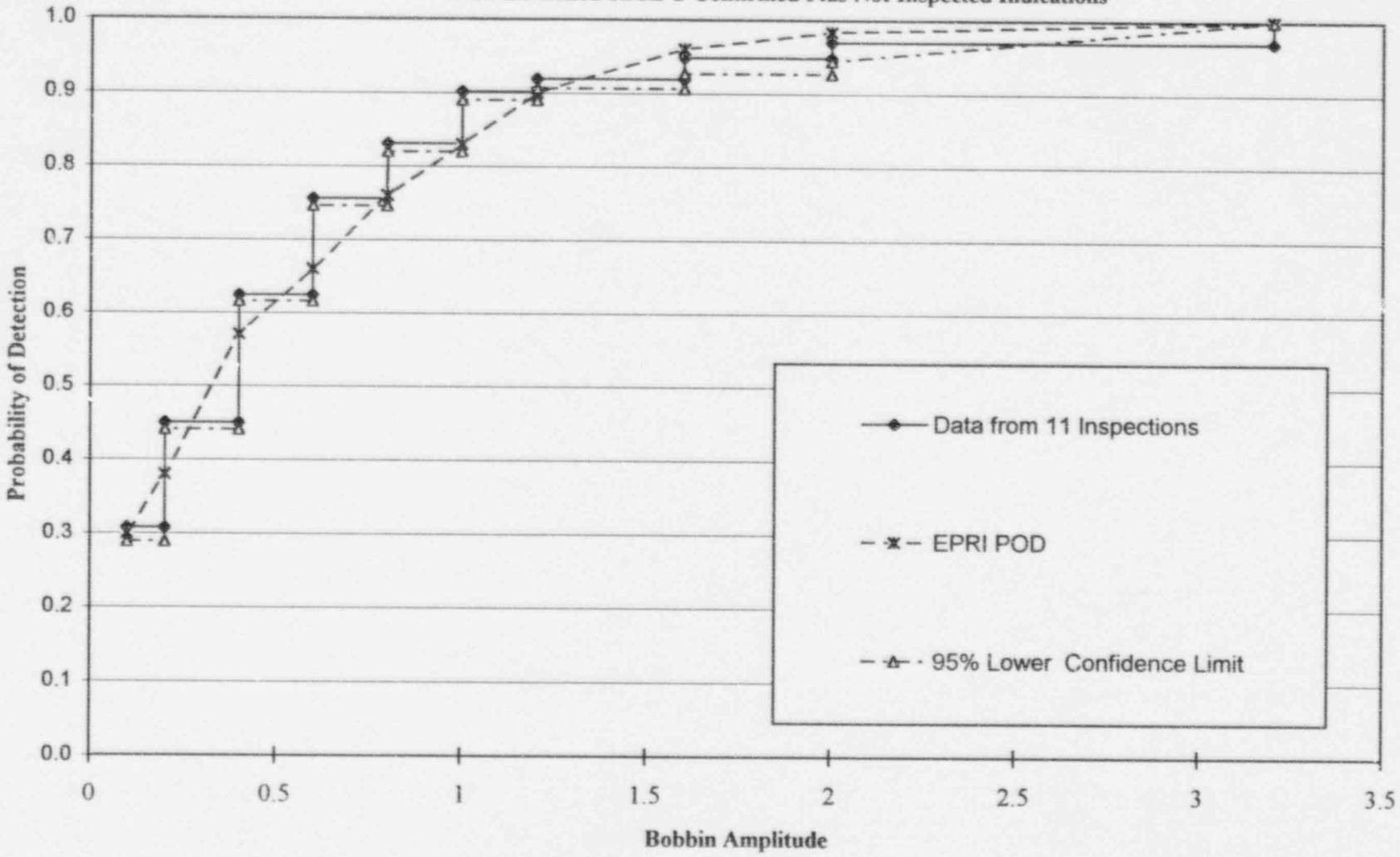


Figure 8-4
Combined POPCD Evaluation for 11 Post-92 Inspections
POPCD Based on RPC Confirmed Indications Only

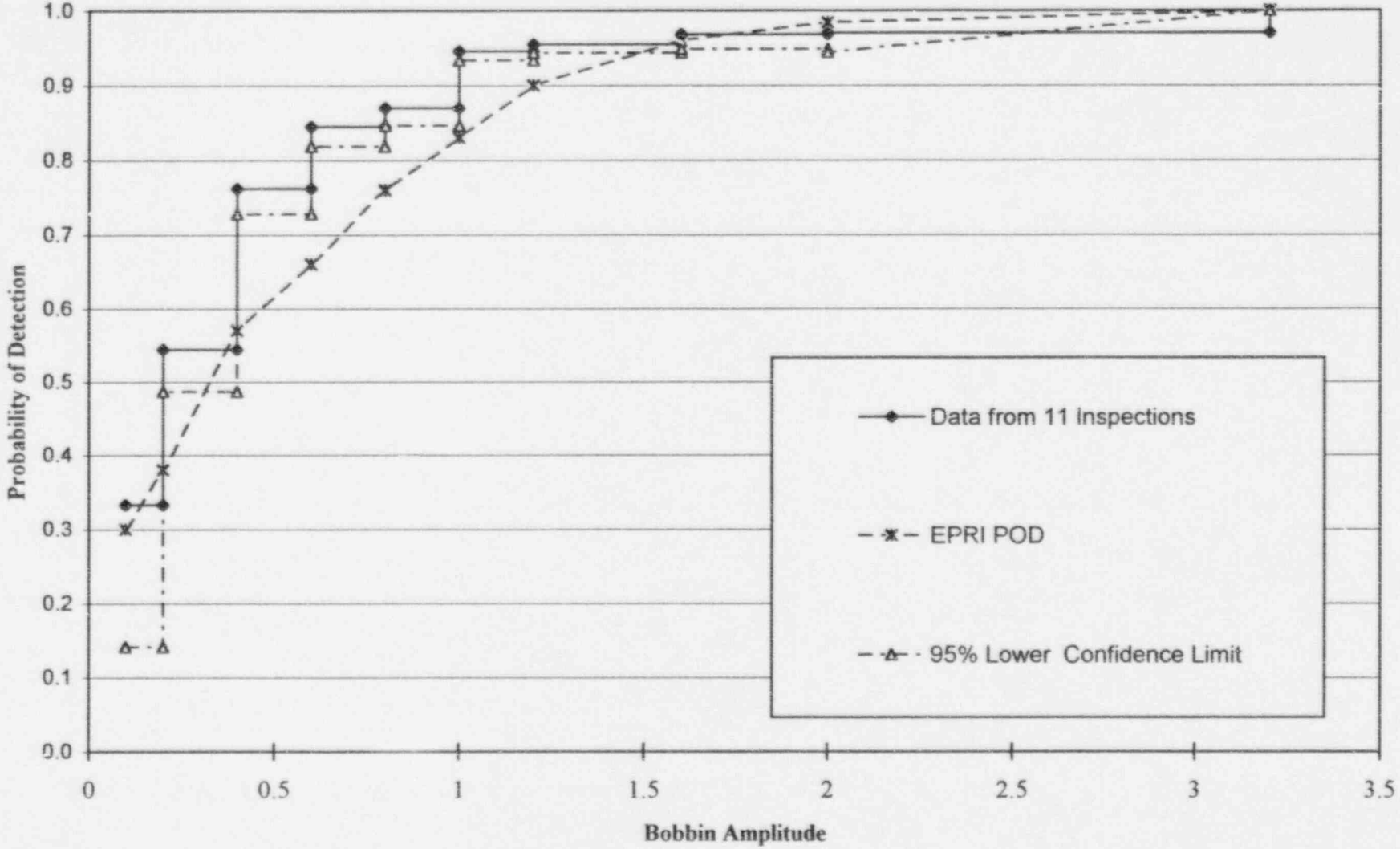


Figure 8-5
Combined POPCD Evaluation for 11 Post-92 Inspections
POPCD Based on RPC Confirmed Plus Not Inspected Indications

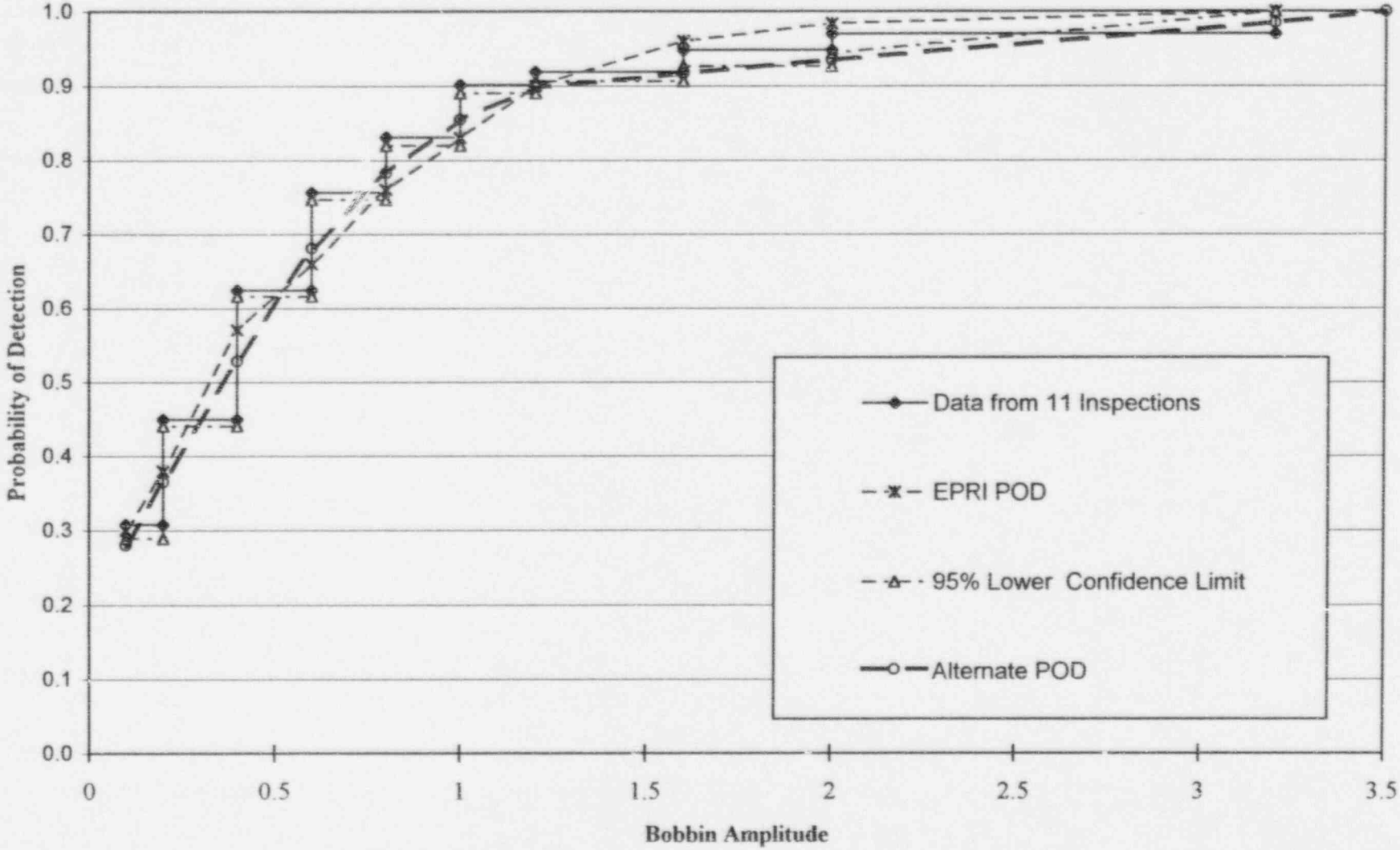
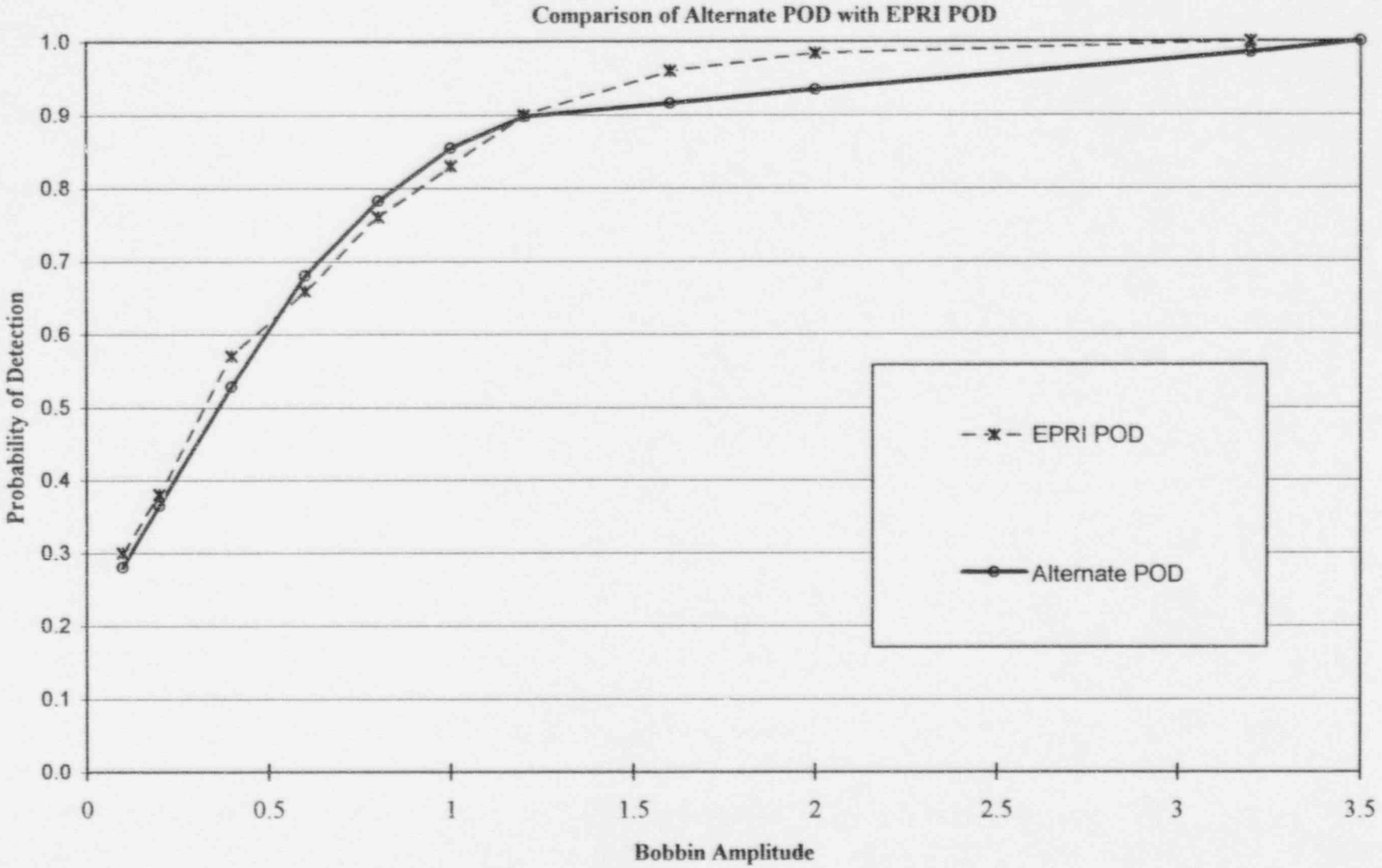


Figure 8-6


Comparison of Alternate POD with EPRI POD
Probability of Detection
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.5
1
1.5
2
2.5
3
3.5
Bobbin Amplitude
EPRI POD
Alternate POD

9.0 REFERENCES

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

9.2 SG-95-06-006, "Beaver Valley Unit-1, Interim Plugging Criteria 90 Day Report," Westinghouse Electric Corporation, May 1995.

9.3 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.

9.4 WCAP-14123 (SG-94-07-009), "Beaver Valley Unit 1 Steam Generator Tube Plugging Criteria for Indications at Tube Support Plates", Westinghouse Electric Corporation, Proprietary Class 2, July 1994.

9.5 WCAP-14277, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections," Westinghouse Nuclear Services Division, January 1995.

9.6 Draft of Addendum-1 to EPRI Report NP-7480-L, "Steam Generator Outside Diameter Stress Corrosion Cracking at Tube Support Plates - Database for Alternate Repair Criteria," June 1996.