WESTINGHOUSE PROPRIETARY CLASS 3

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SG-96-03-001

BYRON UNIT - 1 END-OF-CYCLE 7A

INTERIM PLUGGING CRITERIA REPORT

March 1996

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Byron Unit - 1 End-of-Cycle 7A
Interim Plugging Criteria Report

1.0 Introduction

This report provides the Byron Unit 1 steam generator tube Eddy Current (EC) inspection results at the end of Cycle 7A* together with Steam Line Break (SLB) leak rate and tube burst probability analysis results calculated according to NRC guidelines, in support of the implementation of the recently approved 3.0 volt Interim Plugging Criteria (IPC). SLB leak rates and tube burst probabilities were calculated for end of cycle (EOC) conditions of both the recently completed cycle (Cycle 7A) and the ongoing cycle (Cycle 7B).

Analyses for Cycle 7A were carried out using the actual bobbin voltage distributions measured during the EOC-7A outage and the results compared with corresponding values from projections performed based on the last (EOC-6) inspection bobbin voltage data. The analyses based on the actual measured bobbin voltage distributions for Cycle 7A considered conditions both before and after tube support plate (TSP) locking (to support a 3 volt IPC). However, since the EOC-7A results represent completion of a cycle implementing a 1 volt IPC consistent with NRC guidelines, leak and burst analyses based on the free span analysis methods are the reference analyses. The results based on the assumptions of TSP locking are provided for information as sensitivity analyses.

Analyses were also performed to project leak rates and tube burst probability for postulated SLB conditions at the end of the ongoing cycle (Cycle 7B) based on the 3.0 volt repair criteria. Those analyses utilized bobbin voltage distributions measured during the recent (EOC-7A) inspection and a limiting growth rate distribution established using growth data from EOC-6 and EOC-7A inspections. The methodology used in these evaluations is in accordance with previously published Westinghouse reports (References 8-1, 8-2 and 8-6)

*Since the current inspection is a mid-cycle inspection, for clarity the first-half of Cycle 7 is referred to as Cycle 7A and the second-half as Cycle 7B.

2.0 Summary and Conclusions

SLB leak rate and tube burst probability analyses were performed for the actual EOC-7A EC bobbin voltage distributions as well as the projected EOC-7B bobbin voltage distributions. Results for the EOC-7A actual measured bobbin voltages are considerably lower than the corresponding projections performed using the EOC-6 outage bobbin voltage data and a probability of detection of 0.6, by at least a factor of 14. The large differences between the projections and actuals are due primarily to reduction in voltage growth, particularly for the large voltage tail of the growth distribution. This is also evident from comparison of the highest bobbin voltage projected for each SG at EOC-7A with those actually measured, both shown in Table 7-1. The largest measured voltage was 3.5 volts (adjusted for NDE uncertainty by a Monte Carlo technique) compared to projected 11.7 volts for a constant POD value of 0.6 and 7.8 volts for the EPRI POD. Projections based on a constant POD of 0.6 for EOC-7A predicted SG-C to be the limiting SG; however, analyses based on EOC-7A actual measured voltage distributions indicate a slightly higher leak rate and burst probability for SG-B in comparison to SG-C, but the absolute differences are small. Projections for EOC-7A using the EPRI POD correctly predicted SG-B as the limiting SG. The leak rate and tube burst probability projections at EOC conditions for the current cycle (Cycle 7B) are also well within acceptable limits, with SG-B being the limiting SG for leak. The corresponding tube burst probability is below 4×10^{-6} for all four SGs.

For the actual EOC-7A bobbin voltage distribution, free span SLB leak rate (applicable prior to TSP locking) and tube burst probability are calculated to be 0.075 gpm and 1.3×10^{-3}, respectively, for the limiting SG which is SG-B. These values are considerably below the corresponding EOC-7A projections for SG-B based on EOC-6 voltage distribution adjusted using the NRC SER endorsed probability of detection of 0.6. Also, these values are much lower than the allowable Cycle 7A SLB leakage limit of 12.5 gpm and the NRC reporting guideline of 10^{-2} for the conditional tube burst probability. The corresponding EOC-7A values calculated for a locked TSP condition are 0.075 gpm leak rate and a burst probability of less than 4×10^{-6} (only cold leg indications contribute to burst). Leak rate is not significantly affected by the locked TSP condition due to a low free span burst probability (i.e., only a few indications restrained from burst, would have had a higher leakage). As expected, the tube burst probability is substantially reduced for the locked TSP condition.

Limiting SLB leak rate projected for the EOC-7B conditions (locked TSPs) using the NRC SER endorsed probability of detection of 0.6 is 0.25 gpm. This value is projected for SG-B and it is well below the allowable EOC-7B leakage limit of 12.5 gpm. The corresponding limiting tube burst probability value is less than 4×10^{-6} which is also well below the NRC reporting guideline of 10^{-2}. The burst probability is controlled by cold leg indications (TSPs are not locked on the cold leg side). The projected EOC-7B leak rates are higher than found at the actual EOC-7A condition

due to the requirement to adjust the number of indications upwards using a probability of detection factor of 0.6.

A total of 5005 indications were found in the EOC-7A inspection of which 219 were inspected with a Rotating Pancake Coil (RPC) probe (including a minimum of 20 % of hot leg indications between 1 and 3 volts and all hot leg indications above 3 volts), and 161 were confirmed as flaws. The RPC confirmed indications included 156 above 1.0 volt. SG-B had the largest number among the four SGs with 1602 bobbin indications, of which 264 were above 1.0 volt, 67 of these were inspected by RPC and 51 were confirmed as flaws. Only one indication was found above 3 volts, 3.17 volts in SG-A, and it was confirmed by RPC. No unexpected inspection results were found at the TSP intersections, such as circumferential indications, indications extending outside the TSP or PWSCC at dented TSP intersections.

3.0 EOC-7A Inspection Results and Voltage Growth Rates

3.1 EOC-7A Inspection Results

In accordance with the IPC guidance provided by the NRC Generic Letter 95-05, the end of Cycle 7A inspection of the Byron Unit-1 steam generators (SG) consisted of a complete, 100% EC bobbin probe full length examination of the tube bundles in all four SGs. A 0.610 inch diameter probe was used for all hot and cold leg TSPs where IPC was applied. Subsequently, RPC examination was performed for a minimum of 20 percent of hot leg indications with an amplitude between 1 and 3 volts, all of hot leg indications with an amplitude above 3 volts, and all of cold leg indications with an amplitude above 1 volt. There was only one hot leg indication above 3 volts. It was confirmed as a flaw and plugged. None of the cold leg indications had a bobbin voltage above 1 volt.

An augmented RPC inspection was also performed consistent with the NRC requirements. All dented intersections with a bobbin voltage greater than 5 volts and a minimum of 20 percent of intersections with a bobbin dent voltage between 2.5 and 5 volts were inspected with RPC. The augmented RPC inspection also included 8 TSP intersections with mixed residual artifact signals (MRI). There were no RPC flaw indications reported in the augmented inspection.

There was no evidence of any unexpected results in the EOC-7A eddy current inspection data. There were no RPC circumferential indications at the TSPs, no indications extending outside the TSPs, no RPC indications with potential PWSCC phase angles, no flaw indications at dented TSP intersections at any dent voltage and there was no signal interference from copper deposits. Thus, no flaw indications were found in the augmented RPC inspection. All RPC responses were consistent with that expected for ODSCC at TSP intersections.

A summary of EC indications for all four steam generators is shown on Table 3-1, which tabulates the number of field bobbin indications, the number of these field bobbin indications that were RPC inspected, the number of RPC confirmed indications, and the number of plugged indications. Also shown are the total number indications and the number of RPC confirmed or not RPC inspected indications that remain active for Cycle 7B operation. A further separation of bobbin coil data in Table 3-1 into hot and cold leg indications is given in Section 6.

Overall, the combined data for all four steam generators of Byron Unit-1 shows that:

- Out of a total of 5005 indications identified during the inspection, a total of 219 were RPC inspected.

- Of the 219 RPC inspected, a total of 161 were RPC confirmed.

- A total of 525 indications were removed from service, but only 40 indications were in tubes repaired for TSP IPC-related causes (and the rest in tubes repaired for other reasons). Consistent with the new 3 volt IPC, RPC confirmed hot leg indications with bobbin amplitude of less than or equal 3.0 volts and RPC confirmed cold leg indications less than or equal to 1 volt are not considered for removal from service.

A review of Table 3-1 indicates that although a few more indications were found in SG-B (1602) than in SG-C (1595), more indications (a quantity of 1544, with 244 indications above 1.0 volt) are returned to service in SG-C. However, SG-B has more larger indications (above 2 volts, which are the dominant contributors to SLB leak rate and tube burst probability) returned to service, thereby it potentially could be the limiting SG at EOC-7B. Also, it is noted that SG-A has the largest indication (3.17 volts) found in the EOC-7A inspection. As discussed in Section 7, SG-B bobbin voltage distribution yielded the largest SLB leak rate projected for the EOC-7B condition.

Figure 3-1 shows the actual bobbin voltage distribution determined from the EOC-7A EC inspection; Figure 3-2 shows the population distribution of those EOC-7A indications removed from service due to tube repairs; Figure 3-3 shows the distribution for indications returned to service for Cycle 7B. Of the 525 indications removed from service, only 40 indications are in tubes repaired for TSP IPC-related issues and the rest are in tubes plugged for degradation mechanisms other than ODSCC at TSP's. Among the 40 ODSCC indications removed from service due to IPC-related issues, only one indication was above the 3 volt IPC limit. Among the remaining 39 indications, 23 are in tubes near the wedge supports for which TSP IPC does not apply and 16 are in tubes expanded to lock TSPs for application of a 3 volt IPC. Of the 16 indications in expanded tubes, tube expansions were performed at four TSP intersections having indications with small voltages of 0.42, 0.51, 0.72 and 0.97 volt.

The distribution of EOC-7A 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 (4689 out of 5005 indications occurred at the first three hot leg TSP intersections), although the mechanism extended to higher TSPs. Only 8 indications were detected on the cold leg side. This distribution indicates the predominant temperature dependence of ODSCC at Byron 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 7B

operation, voltage growth rates were developed from EOC-7A (November 1995) inspection data and a reevaluation of the same indications from the EOC-6 (December 1994) inspection EC signals. Table 3-3 shows the cumulative probability distribution of growth rate for each Byron Unit-1 steam generator during Cycle 7A (January '95 - November '95) on an EFPY basis, along with the corresponding Cycle 6 growth rate distributions. Cycle 7A growth data is also plotted in Figure 3-5. Among the four steam generators, SG-D has a slightly larger average voltage growth during Cycle 7A. The curve labelled 'cumulative' in Figure 3-5 represents averaged composite growth data from all four SGs. Average growth rates for each SG during Cycle 7A are summarized in Table 3-4. The average growth rates over the entire voltage range vary between 43.8% and 59.5% (of the BOC voltage) per EFPY, between SGs, with an overall average of 48.3% per EFPY. The average growth for indications greater than or equal to 0.75 volts is 37.7% per EFPY and for indications less than 0.75 volts it is 52.1% per EFPY. Steam generators B and C had the highest average voltage at BOC-7A whereas SG-D had the largest average voltage growth during Cycle 7A. Steam generator A had the largest voltage growth rate during the last (EOC-6) inspection.

Averaged composite voltage growth data from all four steam generators for the last two operating periods are summarized in Table 3-5. For EOC-4 and EOC-5 inspections, growth rates are available only for tubes plugged during the inspection and those data are also included in Table 3-5. Figure 3-6 provides a comparison of the growth rate distributions for the last two operating periods. Growth rates for Cycle 7A are significantly below those observed for Cycle 6.

Table 3-6 lists top 30 indications on the basis of Cycle 7A growth rates, in descending order. Eight of those indications were either RPC NDD or were not RPC inspected. Six of the 30 indications shown are new indications, and EOC-6 voltages used to estimate growth rates for them were obtained by revaluating the last inspection data.

The guidelines in the Generic Letter 95-05 require the use of the more conservative growth rate distributions from the past two inspections for projecting EOC distributions for the next cycle. From Figure 3-6 it is evident that growth rates for Cycle 6 are higher than those of Cycle 7A. Therefore, Cycle 6 growth rates were used to develop the EOC-7B predictions. The actual growth distribution used for EOC-7B projection is a worst case hybrid growth distribution that was developed during the last inspection (EOC-6) and applied to project EOC-7A voltage distributions. This limiting growth rate distribution envelopes the actual EOC-6 distribution with the simultaneous limitations of SG-A (highest average growth) and of SG-C (highest growth increment of 9.9 volts). Table 3-7 compares this hybrid growth distribution with the growth distributions observed for SG-B (highest growth rate for indications above 0.75 volts at BOC-7A) and SG-D (highest average growth rate) during Cycle-7A. It is evident that the hybrid growth distribution is more conservative than the Cycle 7A growth rate distribution. This

conservative growth distribution was imposed on all four steam generators, to provide a conservative basis for predicting EOC-7B performance.

Separate voltage projections to EOC-7B are required for the hot and cold legs since tube expansion to limit TSP displacement has been implemented only in the hot leg. Table 3-2 shows average and maximum growth rates by TSP elevation including the cold leg. It is seen that no large growth rates were found for the cold leg with 0.23 volts as the largest growth value. The cold leg results tend to indicate lower growth rates than found for hot leg indications. It is therefore very conservative to use the bounding growth rate (Cycle 6 distribution) for the cold leg as well as the hot leg indications, and this conservatism is applied for the EOC-7B analysis in Sections 6 and 7.

3.3 NDE Uncertainties

The NDE uncertainties applied for the Cycle 7A voltage distributions in the Monte Carlo analyses for leak rate and burst probabilities are the same as those previously reported in the Braidwood Unit-1 IPC report of Reference 8-1 and NRC GL 95-05. They are presented in Table 3-8 as well as graphically illustrated in Figure 3-7. The probe wear uncertainty has a standard deviation of 7.0 % about a mean of zero and has a cutoff at 15 % based on implementation of the probe wear standard. The analyst variability uncertainty has a standard deviation of 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-7B voltage distributions.

3.4 Assessment of RPC Confirmation Rates

This section tracks the 1994 EOC-6 indications left in service at BOC-7A relative to RPC inspection results in 1995 at EOC-7A. The composite results for all SGs are given in Table 3-9. For 1994 bobbin indications left in service, the indications are tracked relative to 1994 RPC confirmed, 1994 RPC NDD, 1994 bobbin indications not RPC inspected and 1994 bobbin indications with no indication found in 1995. Also included are new 1995 indications. The table shows, for each category of indications, the number of indications RPC inspected and RPC confirmed in 1995 as well as the percentage of RPC confirmed indications.

Of the 149 RPC NDD indications left in service at BOC-7A, 27 were RPC tested during the EOC-7A inspection and 13 were confirmed. This RPC confirmation rate for prior RPC NDD indications (48%) is slightly higher than that typically found for other plants during recent inspections. It has been recommended by industry that the largest RPC NDD confirmation rates over the prior two cycles be used for projections. Since data from only one inspection is currently available, it is

recommended that future Byron-1 IPC applications include only about 50% of the RPC NDD indications in the BOC voltage distribution used for EOC projections, and leak rate and burst probability analyses. However, 100% of RPC NDD indications reported in the EOC-7A inspection are considered in the SLB leak rate and tube burst probability analyses presented in this report for EOC-7A and EOC-7B conditions.

Table 3-1 (Sheet 1 of 2)
Byron Unit -1 November 1995 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 7A

Voltage Bin	Steam Generator A						Steam Generator B						Steam Generator C					
	In-Service During Cycle 7A				RTS for Cycle 7B		In-Service During Cycle 7A				RTS for Cycle 7B		In-Service During Cycle 7A				RTS for Cycle 7B	
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.2	6	0	0	0	6	6	8	0	0	0	8	8	13	1	0	0	13	12
0.3	47	0	0	4	43	43	95	2	1	2	93	92	71	0	0	0	71	71
0.4	132	3	0	13	119	116	199	1	0	10	189	188	157	3	0	3	154	151
0.5	141	3	1	13	128	126	209	2	1	16	193	193	251	1	1	3	248	248
0.6	149	2	0	16	133	131	221	4	2	13	208	206	225	7	3	5	220	216
0.7	98	1	0	7	91	90	215	2	1	17	199	198	214	3	1	8	206	204
0.8	86	2	0	12	74	72	171	1	0	15	156	155	171	1	0	4	167	166
0.9	79	1	1	8	71	71	124	3	1	6	118	116	129	1	1	6	123	123
1	50	0	0	7	43	43	95	1	1	2	93	93	101	3	1	3	98	96
1.1	32	1	1	5	27	27	72	8	6	13	59	57	78	6	2	3	75	71
1.2	37	1	1	4	33	33	56	8	6	17	39	37	54	0	0	1	53	53
1.3	22	2	2	1	21	21	39	8	7	13	26	26	39	4	4	1	38	38
1.4	11	3	2	0	11	10	16	3	3	4	12	12	35	9	7	0	35	33
1.5	7	3	3	1	6	6	26	2	2	8	18	18	14	8	8	0	14	14
1.6	10	7	7	1	9	9	15	6	5	7	8	8	14	9	9	5	9	9
1.7	3	1	0	0	3	2	5	1	1	1	4	4	11	7	7	2	9	9
1.8	4	2	2	1	3	3	11	0	0	1	10	10	5	2	2	1	4	4
1.9	4	2	2	2	2	2	9	1	1	4	5	5	2	2	2	1	1	1
2	1	1	1	0	1	1	2	1	1	1	1	1	3	2	2	3	0	0
2.1	0	0	0	0	0	0	2	2	1	0	2	1	2	2	2	0	2	2
2.2	0	0	0	0	0	0	4	4	4	1	3	3	2	1	1	0	2	2
2.3	2	2	2	0	2	2	1	1	1	0	1	1	0	0	0	0	0	0
2.4	0	0	0	0	0	0	3	3	3	1	2	2	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	1	1	1
2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.7	0	0	0	0	0	0	1	1	1	0	1	1	2	2	2	1	1	1
3	0	0	0	0	0	0	2	2	2	1	1	1	0	0	0	0	0	0
3.2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	922	38	26	96	826	814	1602	67	51	153	1449	1436	1595	76	57	51	1544	1525
> 1V	134	26	24	16	118	116	264	51	44	72	192	187	263	56	50	19	244	238

Table 3-1 (Sheet 2 of 2)
Byron Unit -1 November 1995 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 7A

Voltage Bin	Steam Generator D						Composite of All 4 SGs					
	In-Service During Cycle 7A				RTS for Cycle 7B		In-Service During Cycle 7A				RTS for Cycle 7B	
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.2	9	1	0	4	5	5	36	2	0	4	32	31
0.3	88	0	0	25	63	63	301	2	1	31	270	269
0.4	144	4	1	31	113	110	632	11	1	57	575	565
0.5	121	0	0	23	98	98	722	6	3	55	667	665
0.6	126	3	1	33	93	91	721	16	6	67	654	644
0.7	109	3	3	35	74	74	637	9	5	67	570	566
0.8	70	2	2	21	49	49	498	6	2	52	446	442
0.9	62	0	0	20	42	42	394	5	3	40	354	352
1	43	2	0	13	30	28	289	6	2	25	264	260
1.1	30	2	2	7	23	23	212	17	11	28	184	178
1.2	20	1	1	3	17	17	167	10	8	25	142	140
1.3	15	1	1	1	14	14	115	15	14	16	99	99
1.4	13	4	3	3	10	9	75	19	15	7	68	64
1.5	7	3	3	2	5	5	54	16	16	11	43	43
1.6	5	2	2	1	4	4	44	24	23	14	30	30
1.7	9	1	0	3	6	5	28	10	8	6	22	20
1.8	5	0	0	3	2	2	25	4	4	6	19	19
1.9	0	0	0	0	0	0	15	5	5	7	8	8
2	3	2	2	0	3	3	9	6	6	4	5	5
2.1	1	1	1	0	1	1	5	5	4	0	5	4
2.2	1	1	1	1	0	0	7	6	6	2	5	5
2.3	1	1	0	0	1	0	4	4	3	0	4	3
2.4	0	0	0	0	0	0	3	3	3	1	2	2
2.5	0	0	0	0	0	0	2	2	2	1	1	1
2.6	1	1	1	0	1	1	1	1	1	0	1	1
2.7	1	1	1	1	0	0	4	4	4	2	2	2
3	2	2	2	1	1	1	4	4	4	2	2	2
3.2	0	0	0	0	0	0	1	1	1	1	0	0
Total	886	38	27	231	655	645	5005	219	161	531	4474	4420
> 1V	114	23	20	26	88	85	775	156	138	133	642	626

Table 3-2 (Sheet 1 of 2)
Byron Unit-1 November 1995
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 7A

Tube Support Plate	Steam Generator A					Steam Generator B					Steam Generator C				
	Number of Indications	Maximum Voltage	Average Voltage	Maximum Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Maximum Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Maximum Growth	Average Growth
3H	479	3.17	0.70	1.42	0.21	959	2.95	0.76	2.13	0.23	992	2.67	0.73	1.79	0.20
5H	256	2.21	0.67	1.28	0.21	421	2.36	0.66	1.43	0.19	469	2.17	0.70	1.09	0.20
7H	103	1.62	0.67	0.86	0.21	111	1.85	0.59	0.85	0.13	48	1.53	0.61	0.84	0.18
8H	45	1.71	0.62	0.71	0.18	82	1.38	0.56	0.55	0.15	53	1.27	0.58	0.64	0.12
9H	26	1.36	0.52	0.35	0.11	21	0.87	0.51	0.37	0.10	24	1.11	0.48	0.6	0.17
10H	10	0.85	0.54	0.44	0.21	5	0.54	0.41	0.21	0.13	2	0.96	0.84	0.28	0.27
11H	0	-	-	-	-	0	-	-	-	-	6	0.78	0.46	0.18	0.08
11C	0	-	-	-	-	2	0.78	0.61	0.21	0.09	0	-	-	-	-
10C	1	0.42	0.42	0.21	0.21	0	-	-	-	-	0	-	-	-	-
9C	1	0.4	0.40	0.01	0.01	0	-	-	-	-	0	-	-	-	-
8C	1	0.34	0.34	-0.09	-0.09	0	-	-	-	-	0	-	-	-	-
7C	0	-	-	-	-	1	1.05	1.05	0.23	0.23	0	-	-	-	-
5C	0	-	-	-	-	0	-	-	-	-	1	0.59	0.59	0.2	0.20
Total	922					1602					1595				

Table 3-2 (Sheet 2 of 2)
Byron Unit-1 November 1995
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 7A

Tube Support Plate	Steam Generator D					Composite of All Four SGs				
	Number of Indications	Maximum Voltage	Average Voltage	Maximum Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Maximum Growth	Average Growth
3H	534	2.93	0.70	1.87	0.25	2964	3.17	0.73	2.13	0.22
5H	251	2.57	0.59	1.49	0.20	1397	2.57	0.66	1.49	0.20
7H	66	2.3	0.55	0.89	0.16	328	2.3	0.61	0.89	0.17
8H	12	0.72	0.46	0.36	0.13	192	1.71	0.57	0.71	0.15
9H	14	0.55	0.33	0.22	0.05	85	1.36	0.47	0.6	0.12
10H	4	0.33	0.28	0.06	-0.01	21	0.96	0.49	0.44	0.16
11H	4	0.5	0.37	0.13	0.07	10	0.78	0.42	0.18	0.08
11C	0	-	-	-	-	2	0.78	0.61	0.21	0.09
10C	0	-	-	-	-	1	0.42	0.42	0.21	0.21
9C	0	-	-	-	-	1	0.4	0.40	0.01	0.01
8C	0	-	-	-	-	1	0.34	0.34	-0.09	-0.09
7C	0	-	-	-	-	1	1.05	1.05	0.23	0.23
5C	1	0.15	0.15	0	0.00	2	0.59	0.37	0.2	0.10
Total	886					5005				

GROWTH.XLS[Table3-2(2of2)]2/9/9647:41 PM

Table 3-3
Byron Unit-1 November 1995
Signal Growth Statistics For Cycle 7A on an EFPY Basis

Delta Volts	Steam Generator A			Steam Generator B			Steam Generator C			Steam Generator D			Cumulative		
	Cycle 6	Cycle 7A		Cycle 6	Cycle 7A		Cycle 6	Cycle 7A		Cycle 6	Cycle 7A		Cycle 6	Cycle 7A	
	CPDF	No. of Obs	CPDF	CPDF	No. of Obs	CPDF	CPDF	No. of Obs	CPDF	CPDF	No. of Obs	CPDF	CPDF	No. of Obs	CPDF
-0.5	0.001	0	0	0	0	0	0	0	0	0.000	0	0	0.000	0	0
-0.4	0.004	0	0	0	1	0.0006	0	0	0	0.000	0	0	0.001	1	0.0002
-0.3	0.004	0	0	0.005	1	0.0012	0.009	0	0	0.000	1	0.0011	0.005	2	0.0006
-0.2	0.011	2	0.002	0.035	6	0.0050	0.027	5	0.003	0.017	1	0.0023	0.024	14	0.0034
-0.1	0.026	15	0.018	0.081	25	0.0206	0.072	29	0.021	0.052	12	0.0158	0.060	81	0.0196
0	0.057	58	0.081	0.170	151	0.1149	0.152	166	0.125	0.124	70	0.0948	0.128	445	0.1085
0.1	0.196	206	0.305	0.350	409	0.3702	0.297	407	0.381	0.339	205	0.3262	0.293	1227	0.3536
0.2	0.399	181	0.501	0.546	327	0.5742	0.443	291	0.563	0.537	183	0.5327	0.476	982	0.5499
0.3	0.590	180	0.696	0.660	248	0.7291	0.591	244	0.716	0.739	141	0.6919	0.633	813	0.7123
0.4	0.726	124	0.831	0.770	150	0.8227	0.720	183	0.831	0.846	87	0.7901	0.755	544	0.8210
0.5	0.805	61	0.897	0.868	84	0.8752	0.825	85	0.884	0.907	56	0.8533	0.845	286	0.8781
0.6	0.874	38	0.938	0.923	69	0.9182	0.891	64	0.924	0.930	52	0.9120	0.902	223	0.9227
0.7	0.928	21	0.961	0.955	41	0.9438	0.924	43	0.951	0.961	25	0.9402	0.940	130	0.9487
0.8	0.951	13	0.975	0.974	20	0.9563	0.945	27	0.968	0.987	16	0.9582	0.962	76	0.9638
0.9	0.969	12	0.988	0.984	19	0.9682	0.969	20	0.981	0.989	8	0.9673	0.976	59	0.9756
1	0.976	4	0.992	0.988	15	0.9775	0.978	8	0.986	0.993	10	0.9786	0.983	37	0.9830
1.1	0.979	0	0.992	0.991	12	0.9850	0.980	7	0.990	0.993	5	0.9842	0.985	24	0.9878
1.2	0.984	3	0.996	0.993	4	0.9875	0.983	6	0.994	0.996	3	0.9876	0.988	16	0.9910
1.3	0.985	1	0.997	0.995	9	0.9931	0.986	5	0.997	0.996	5	0.9932	0.990	20	0.9950
1.4	0.988	1	0.998	0.995	3	0.9950	0.991	1	0.997	0.996	1	0.9944	0.992	6	0.9962
1.5	0.991	1	0.999	0.996	3	0.9969	0.992	1	0.998	0.996	1	0.9955	0.993	6	0.9974
1.6	0.994	0	0.999	0.997	0	0.9969	0.993	1	0.999	0.996	0	0.9955	0.995	1	0.9976
1.7	0.995	1	1	0.997	1	0.9975	0.994	0	0.999	0.996	0	0.9955	0.995	2	0.9980
1.8	0.995			0.997	2	0.9988	0.997	1	0.999	0.998	2	0.9977	0.996	5	0.9990
1.9	0.995			0.997	0	0.9988	0.997	0	0.999	0.998	0	0.9977	0.996	0	0.9990
2	0.995			0.998	0	0.9988	0.997	0	0.999	0.998	1	0.9989	0.997	1	0.9992
2.1	0.995			0.998	1	0.9994	0.997	1	1	0.998	0	0.9989	0.997	2	0.9996
2.2	0.995			0.998	0	0.9994	0.997			0.998	1	1	0.997	1	0.9998
2.3	0.996			0.998	0	0.9994	0.998			0.998			0.997	0	0.9998
2.4	0.996			0.999	0	0.9994	0.999			0.998			0.998	0	0.9998
2.5	0.995			0.998	1	1	0.997			0.998			0.998	1	1
2.9	0.996			1			0.999			0.998			0.998		
3	0.996						0.999			1			0.999		
4.3	0.998						0.999						0.999		
4.7	0.999						0.999						0.999		
5.3	1						0.999						0.9997		
7.8							1						1		
Total		922			1602			1595			886			5005	

GROWTH.XLS Table 3-5

Table 3-4
Byron Unit -1 November 1995 Outage
Average Voltage Growth During Cycle 7A

Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Percent Growth	
			Entire Cycle	Per EFPY #	Entire Cycle	Per EFPY #
	Composite of All Steam Generator Data					
Entire Voltage Range	5005	0.49	0.204	0.235	41.9%	48.3%
V_{BOC} < .75 Volts	4276	0.42	0.189	0.217	45.3%	52.1%
≥ .75 Volts	729	0.90	0.298	0.343	32.9%	37.9%
	Steam Generator A					
Entire Voltage Range	922	0.47	0.207	0.238	44.0%	50.6%
V_{BOC} < .75 Volts	803	0.41	0.192	0.221	47.3%	54.4%
≥ .75 Volts	119	0.91	0.309	0.356	34.0%	39.1%
	Steam Generator B					
Entire Voltage Range	1602	0.51	0.203	0.233	40.1%	46.2%
V_{BOC} < .75 Volts	1356	0.44	0.178	0.205	41.0%	47.2%
≥ .75 Volts	246	0.89	0.337	0.388	37.8%	43.5%
	Steam Generator C					
Entire Voltage Range	1595	0.51	0.195	0.225	38.1%	43.8%
V_{BOC} < .75 Volts	1328	0.43	0.184	0.212	42.5%	48.9%
≥ .75 Volts	267	0.90	0.251	0.288	27.7%	31.9%
	Steam Generator D					
Entire Voltage Range	886	0.43	0.221	0.254	51.7%	59.5%
V_{BOC} < .75 Volts	789	0.37	0.210	0.241	57.3%	65.9%
≥ .75 Volts	97	0.92	0.314	0.361	33.9%	39.0%

Based on Cycle 7A duration of 317.4 EFPD (0.869 EFPY)

Table 3-5
Byron Unit-1 November 1995
Average Voltage Growth for Cycle 7A
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 7A (1994 - 1995) - 317.4 EFPD					
Entire Voltage Range	5005	0.49	0.204	0.235	41.9%	48.3%
V_{BOC} < .75 Volts	4276	0.42	0.189	0.217	45.3%	52.1%
≥ .75 Volts	729	0.90	0.298	0.343	32.9%	37.9%
	Cycle 6 (1993 - 1994) - 466.5 EFPD					
Entire Voltage Range	2851	0.47	0.320	0.251	68.1%	53.3%
V_{BOC} < .75 Volts	2377	0.37	0.35	0.274	94.6%	74.1%
≥ .75 Volts	474	0.99	0.180	0.141	18.2%	14.2%
	Cycle 5 (1991 - 1993) - 411.6 EFPD (Plugged Tubes Only)					
Entire Voltage Range	532	0.46	0.310	0.275	67.4%	59.8%
	Cycle 4 (1990 - 1991) - 463.9 EFPD (Plugged Tubes Only)					
Entire Voltage Range	550	0.32	0.260	0.205	81.3%	64.0%

Table 3-6
Byron Unit-1 November 1995
Summary of Largest Voltage Growth Rates for BOC-7A to EOC-7A

Steam Generator				Bobbin Voltage			RPC	New
SG	Row	Col	Elevation	EOC-7A	BOC-7A	Growth	Confirmed ?	Indication ?
B	21	99	03H	2.93	0.8	2.13	Y	Y
D	15	63	03H	2.62	0.75	1.87	Y	N
C	4	10	03H	2.67	0.88	1.79	Y	N
B	2	5	03H	2.62	0.87	1.75	Y	N
D	14	42	03H	2.92	1.18	1.74	Y	N
C	34	87	03H	2.44	0.89	1.55	Y	N
B	2	51	03H	2.39	0.87	1.52	Y	N
B	19	104	03H	2.95	1.45	1.5	Y	Y
D	16	53	03H	1.76	0.27	1.49	N	Y
D	14	42	05H	2.57	1.08	1.49	Y	N
B	5	44	05H	2.36	0.93	1.43	Y	N
C	7	73	03H	1.82	0.51	1.31	Y	N
A	13	4	03H	2.23	0.81	1.42	Y	N
A	3	69	05H	2.21	0.93	1.28	Y	N
B	4	2	03H	1.77	0.49	1.28	N	N
B	21	107	03H	2.23	0.95	1.28	Y	N
B	17	6	03H	2.16	0.89	1.27	Y	N
D	15	55	03H	1.77	0.52	1.25	N	N
C	20	10	03H	2.15	0.92	1.23	Y	N
B	4	56	03H	2.18	0.97	1.21	Y	N
B	7	100	03H	2.32	1.12	1.2	Y	Y
B	10	67	03H	2.14	0.96	1.18	Y	Y
D	13	85	03H	2.07	0.9	1.17	Y	N
C	10	51	03H	1.91	0.75	1.16	N	N
A	7	61	03H	1.61	0.47	1.14	N	N
C	21	7	03H	2.07	0.94	1.13	Y	N
D	19	42	03H	1.51	0.4	1.11	Y	N
B	2	55	05H	1.94	0.84	1.1	N	N
B	28	89	05H	1.53	0.43	1.1	N	Y
D	13	33	05H	1.72	0.62	1.1	N	N

Table 3-7
Byron Unit-1 November 1995
Signal Growth Statistics (on EFPY Basis) Assumed for Limiting Case Projections for Cycle 7B

Delta Volts	Cycle 7A				Cycle 6	
	Steam Generator B		Steam Generator D		Hybrid Growth #	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	0	0	0	0	0	0
-0.4	1	0.001	0	0	0	0
-0.3	1	0.001	1	0.001	0	0
-0.2	6	0.005	1	0.002	0	0
-0.1	25	0.021	12	0.016	0	0
0	151	0.115	70	0.095	46	0.057
0.1	409	0.370	205	0.326	111	0.196
0.2	327	0.574	183	0.533	163	0.399
0.3	248	0.729	141	0.692	153	0.589
0.4	150	0.823	87	0.790	109	0.725
0.5	84	0.875	56	0.853	64	0.804
0.6	69	0.918	52	0.912	55	0.873
0.7	41	0.944	25	0.940	43	0.927
0.8	20	0.956	16	0.958	19	0.950
0.9	19	0.968	8	0.967	14	0.968
1	15	0.978	10	0.979	6	0.975
1.1	12	0.985	5	0.984	2	0.978
1.2	4	0.988	3	0.988	4	0.983
1.3	9	0.993	5	0.993	1	0.984
1.4	3	0.995	1	0.994	2	0.986
1.5	3	0.997	1	0.995	3	0.990
1.6	0	0.997	0	0.995	2	0.993
1.7	1	0.998	0	0.995	1	0.994
1.8	2	0.999	2	0.998	0	0.994
1.9	0	0.999	0	0.998	0	0.994
2	0	0.999	1	0.999	0	0.994
2.1	1	0.999	0	0.999	0	0.994
2.2	0	0.999	1	1	0	0.994
2.3	0	0.999			1	0.995
2.4	0	0.999			0	0.995
2.5	1	1			0	0.995
2.9					0	0.995
3					0	0.995
4.3					1	0.996
4.7					1	0.998
5.3					1	0.999
7.8					1	1
Total	1602		886		803	

Cycle 6 steam generator A growth distribution plus the largest growth in steam generator C.

Table 3-8
Probe Wear and Analyst Variability - Tabulated Values

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

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

Table 3-9
Byron Unit-1
Analysis of RPC Data from 1994 and 1995 Inspections
Combined Data from All Four Steam Generators

Group of Indications	Total 1994 Bobbin Indication	Total 1995 Bobbin Indication	Total 1995 RPC Inspected	Total 1995 RPC Confirmed	Percent 1995 RPC Confirmed
Less than or Equal to 1.0 Volt in 1995					
'94 Bobbin Left in Service	1651	1561	17	8	47.1
- '94 RPC Confirmed	11	11	0	0	-
- '94RPC NDD	89	89	11	3	27.3
- '94 RPC Not Inspected	1461	1461	6	5	83.3
- No '95 Bobbin *	90	-	-	-	-
New '95 Indication	-	2669	46	17	37.0
Sum of All '95 Indication	1651	4230	63	25	39.7
Greater than 1.0 Volt in 1995					
'94 Bobbin Left in Service	594	587	122	116	95.1
- '94 RPC Confirmed	6	6	2	2	100.0
- '94RPC NDD	60	60	16	10	62.5
- '94 RPC Not Inspected	521	521	104	104	100.0
- No '95 Bobbin *	7	-	-	-	-
New '95 Indication	-	188	34	25	73.5
Sum of All '95 Indication	594	775	156	141	90.4
All Voltages In 1995					
'94 Bobbin Left in Service	2245	2148	139	124	89.2
- '94 RPC Confirmed	17	17	2	2	100.0
- '94RPC NDD	149	149	27	13	48.1
- '94 RPC Not Inspected	1982	1982	110	109	99.1
- No '95 Bobbin *	97	-	-	-	-
New '95 Indication	-	2857	80	42	52.5
Sum of All '95 Indication	2245	5005	219	166	75.8

* Indications split is based on '94 bobbin voltage

Figure 3-1
Byron Unit -1 October 1995 Outage
Bobbin Voltage Distributions at EOC-7A for Tubes in Service During Cycle 7A

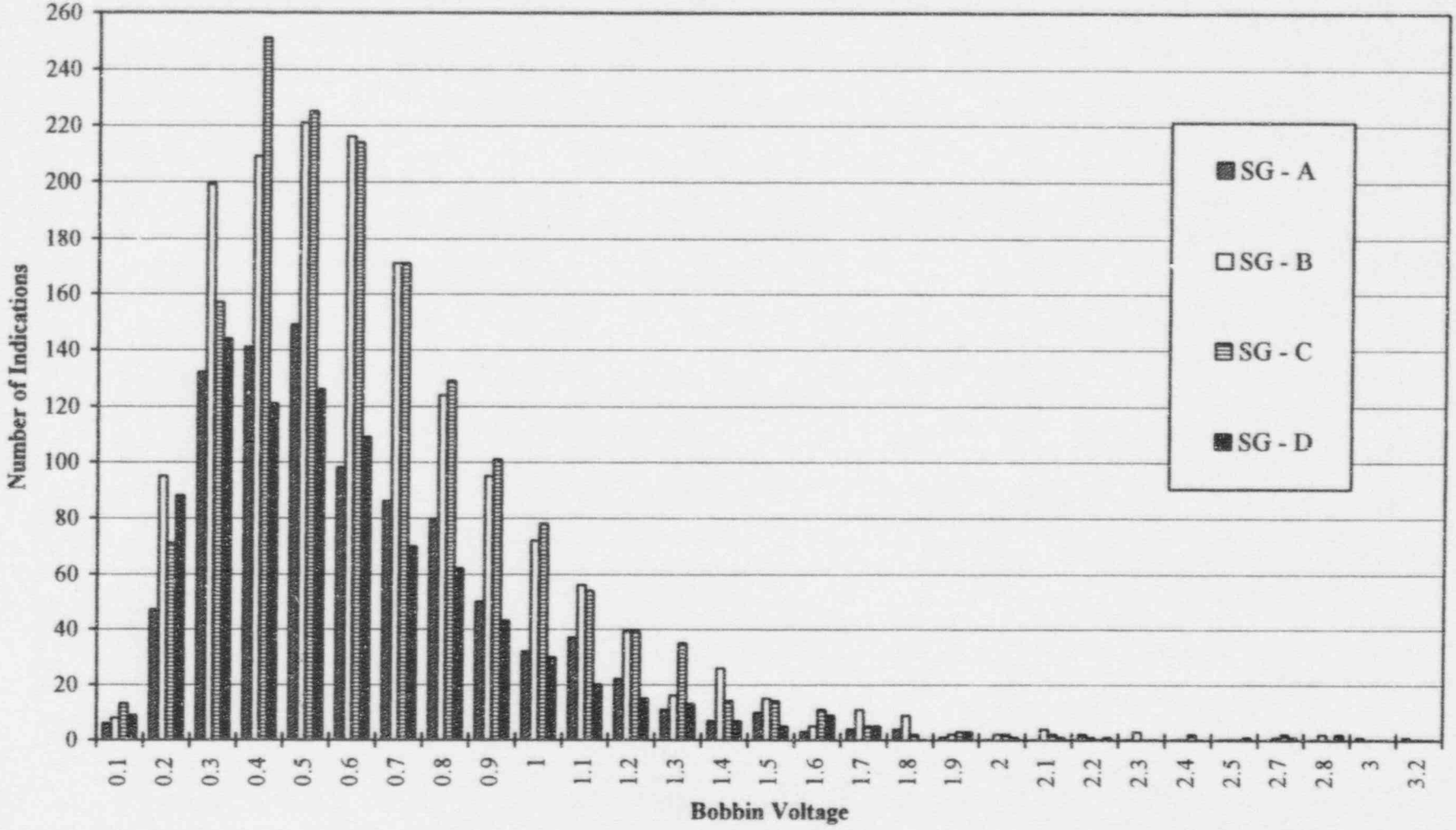

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Figure 3-2
Byron Unit -1 November 1995 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 7A Service

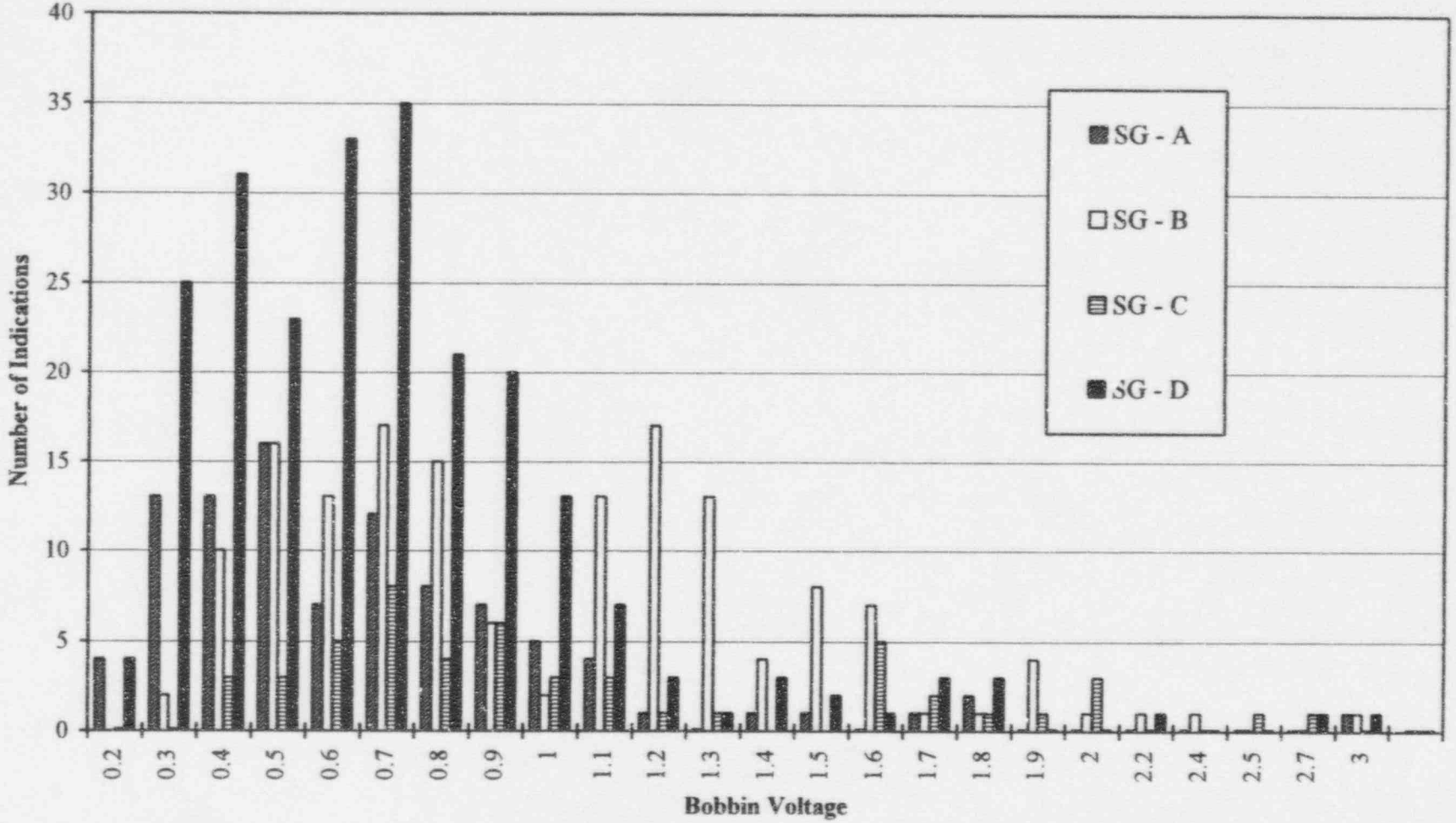

Figure 3-3
Byron Unit -1 November 1995 Outage
Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 7B

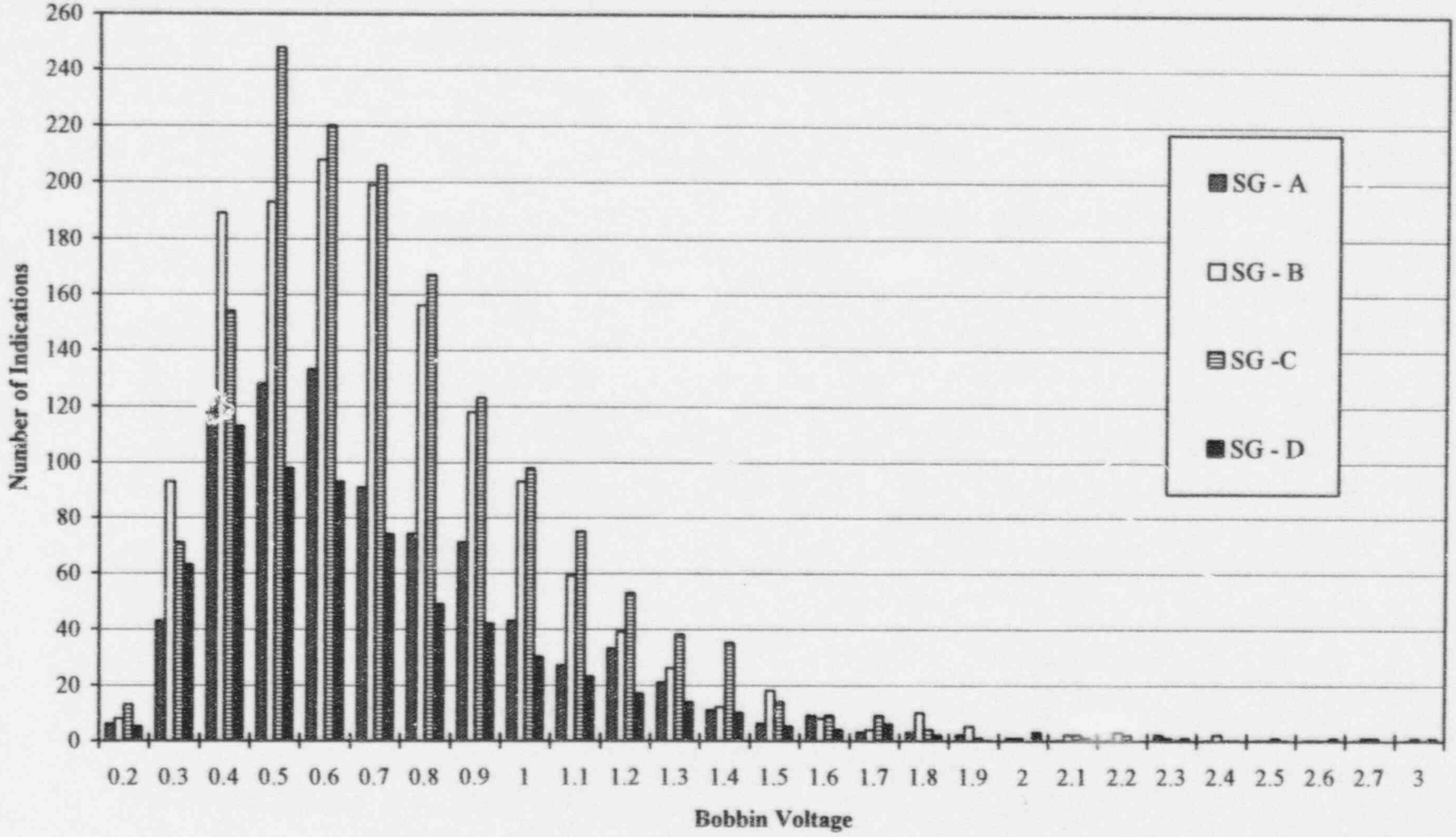

Figure 3-4
Byron Unit-1 November 1995
ODSCC Axial Distributions for Tubes in Service During Cycle 7A

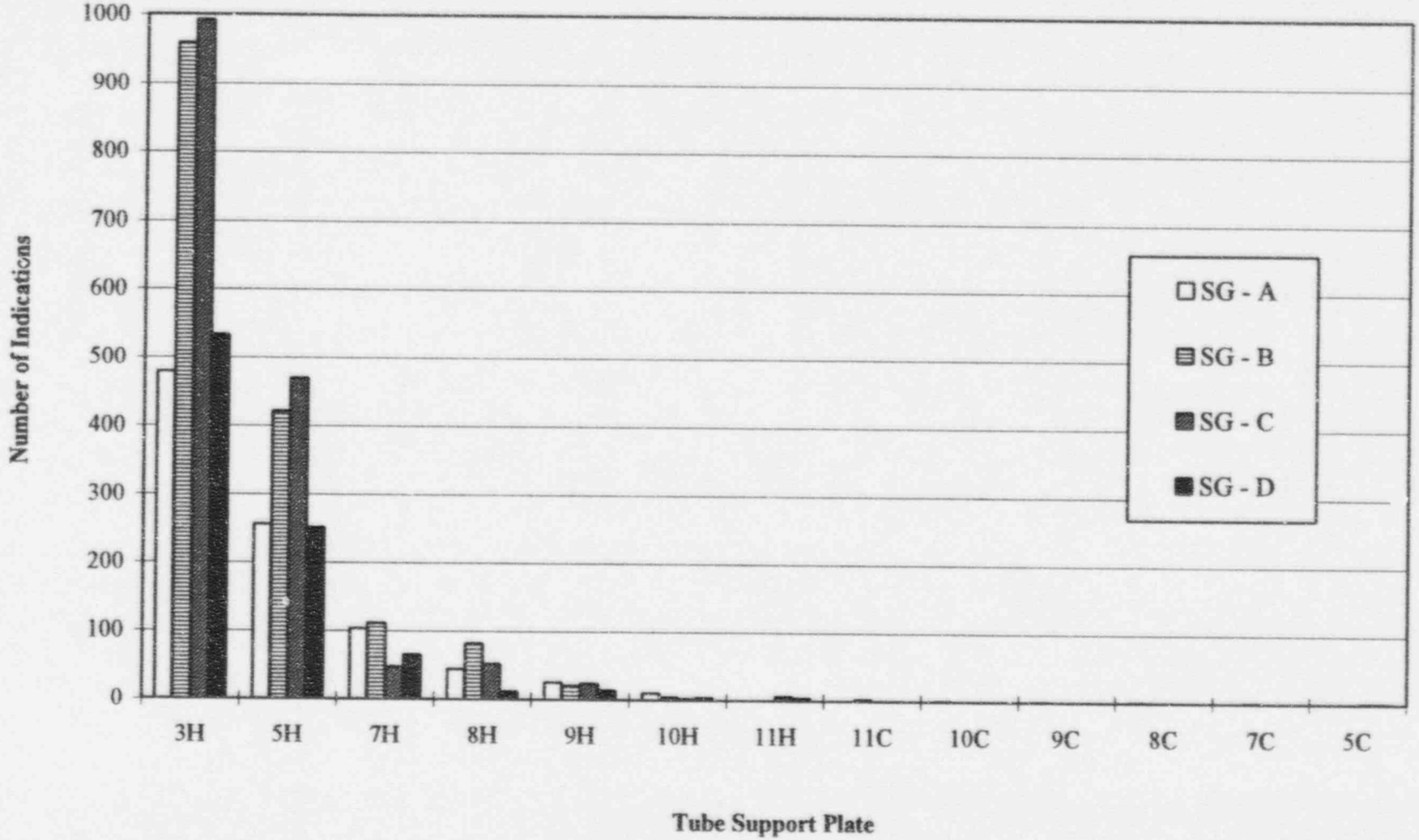

Figure 3-5
Byron Unit -1 Cycle 7A (Dec. 1994 to Nov. 1995)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

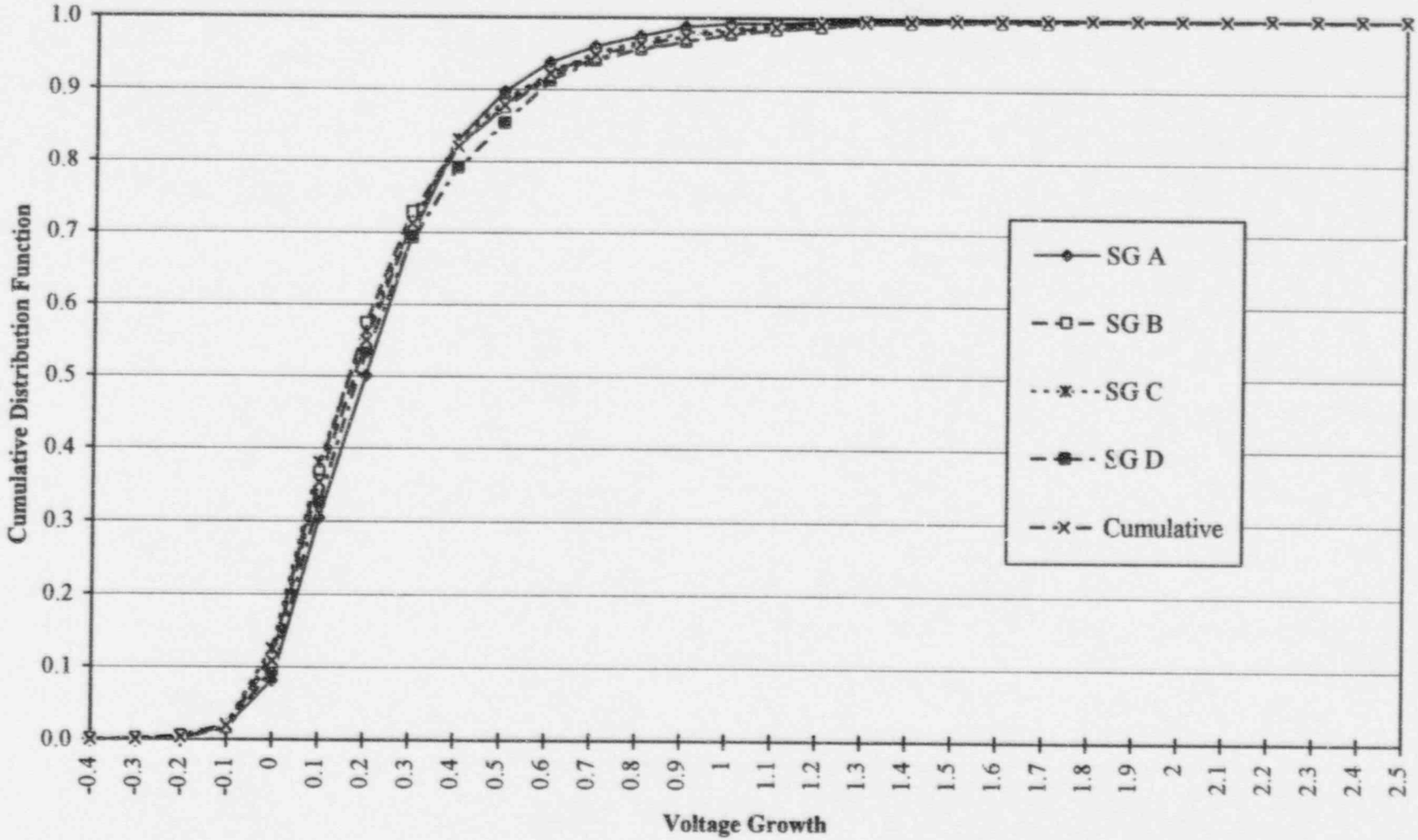

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Figure 3-6
Byron Unit -1 November 1995
Bobbin Signal Growth History - Cumulative Probability Distributions on an EFPY Basis
Composite of All Four Steam Generators

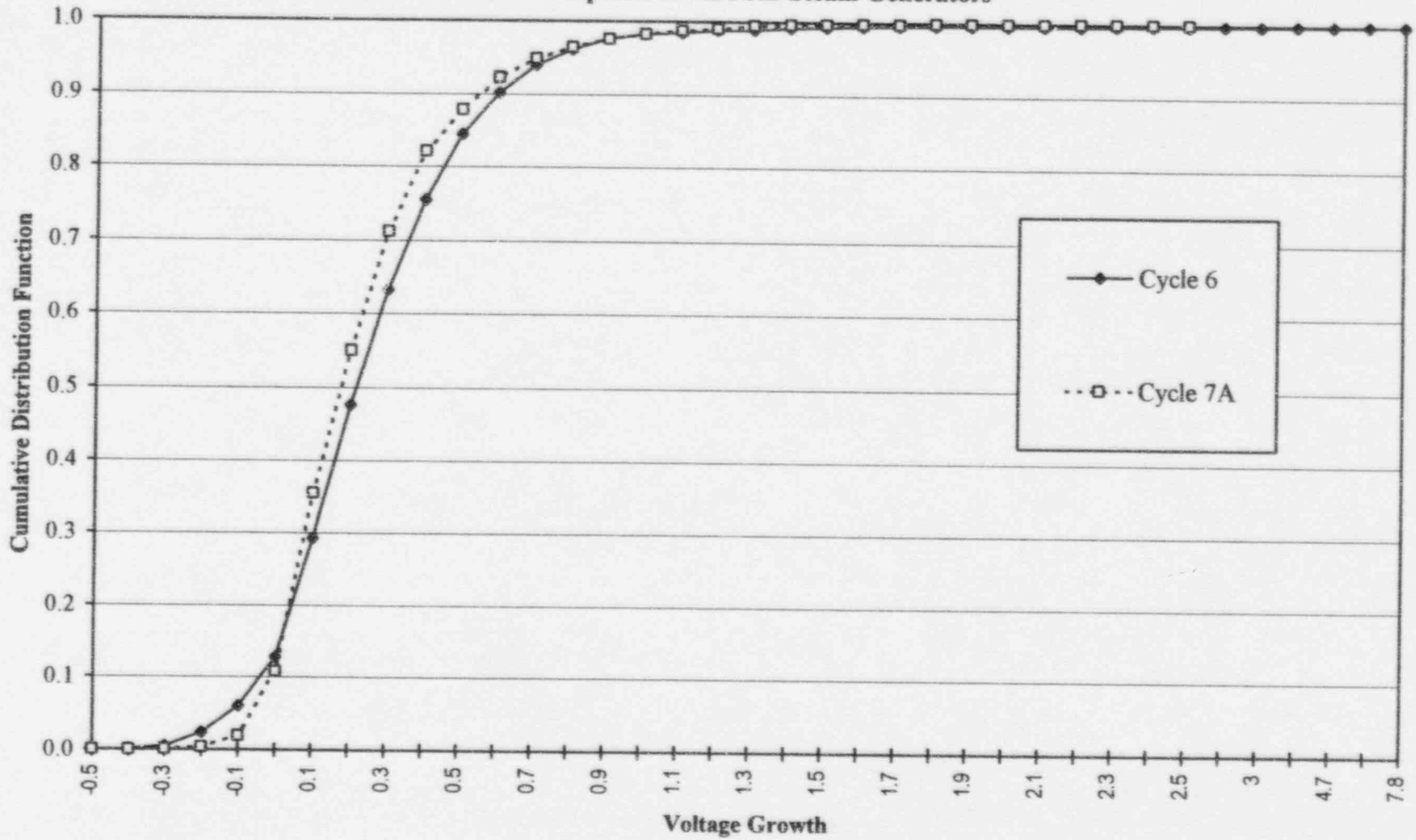


Figure 3-7
NDE Uncertainty Distributions

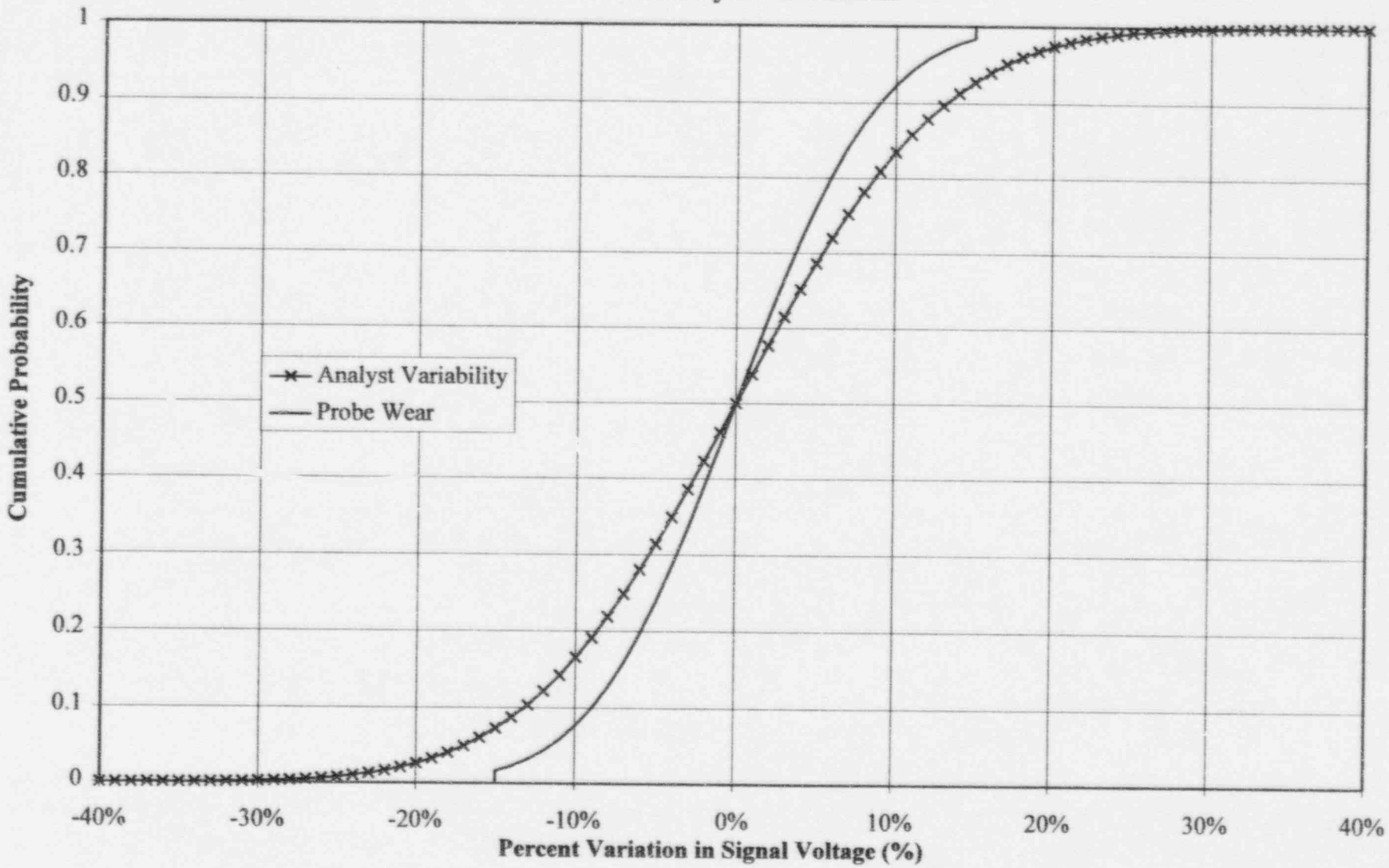


Fig3-7 Chart 1 Fig3-7 Chart 1 3/5/96 12:05 PM

4.0 Database Applied for IPC Correlations

The database used for the IPC correlations that are applied in the analyses of this report are an updated version of the IPC database described in Reference 8-3. Model Boiler specimen 598-1 is excluded from the IPC database based on application of EPRI data exclusion criterion for very high voltage indications and concurrence by the NRC. Byron-1 and Braidwood-1 pulled tube indications R16C42, TSP 5 (0.28 volt) and R20C7, TSP 7 (0.38 volt), respectively, are excluded from the correlation based on EPRI data exclusion criterion 2a accepted by the NRC. Criterion 2a excludes indications with burst pressures high on the voltage correlation if the maximum crack depth is less than 60% and there are less than 2 remaining uncorroded ligaments. Plant S pulled tube indication R28C41 is included in the leak rate correlation at a SLB leak rate of 2496 lph consistent with NRC recommendations.

Recently, South Texas pulled tube data have been added to that IPC database per NRC request. The updated database is in compliance with NRC guidelines for application of leak rate vs voltage correlations and for removal of data outliers in the 3/4 inch tubing burst and leak rate correlations. The updated IPC database was used to perform the SLB leak rate and tube burst probability analyses reported here.

5.0 SLB Analysis Methods

Monte Carlo analyses are used to calculate the SLB leak rates and tube burst probabilities for both actual EOC-7A and projected EOC-7B voltage distributions. The Monte Carlo analyses account for parameter uncertainty and they are consistent with the Byron Unit-1 SER. The analysis methodology is described in Braidwood-1 document Reference 8-1 as well as in the Westinghouse generic methods report of Reference 8-2.

In general, Monte Carlo analyses include POD adjustments, voltage growth and NDE uncertainties in the projected analyses for the next operating cycle while only NDE uncertainties are included in the analyses based on the actual measured voltage distribution (for the cycle just completed). Based on the 3/4" diameter tubing database, the NRC requirement that the p value obtained from the regression analysis be less than or equal to 5% to apply the SLB leak rate versus voltage correlation is satisfied and the correlation is applied for the leak rate analyses of this report.

Two sets of evaluations were performed for this outage evaluation - the first set for the Return-to-Power (RTP) evaluation in December 1995 (Reference 8-7) and the second set for this 90 Day evaluation. To apply the recently NRC approved 3 volt IPC for Byron Unit-1 Cycle 7B operation, tube support plates (TSP) are locked by performing tube expansion on the hot leg side during the recent outage. Therefore, SLB leak rates and tube burst probabilities for the 90 day report were calculated considering the locked TSP condition. With TSP's locked by tube expansion, indications in the hot leg side are restrained from bursting so the burst probability calculations are based only on indications found on the cold side. Since only a small fraction of the indication population are on the cold leg side, the burst probability is expected to be substantially smaller than estimated with the usual IPC/APC methodology (which includes the entire indication population). SLB leak rates and tube burst probabilities for the RTP report were calculated considering conditions both before and after TSP locking; although the analysis without TSP locking assumption is the reference analysis, since a 1 volt IPC applied to Cycle 7A operation. Comparisons of the leak rates and tube burst probabilities calculated by both methods using the actual voltage distributions are made with the corresponding prior projections for EOC-7A.

6.0 Bobbin Voltage Distributions

This section describes salient input data used to calculate EOC bobbin voltage distributions and presents the results of calculations to project EOC-7B voltage distributions. Also, EOC-7A voltage distributions projected based on the EOC-6 inspection bobbin voltage data are compared with the actual bobbin distributions from the current inspection.

6.1 Calculation of Voltage Distributions

The analysis for EOC voltage distribution starts with a cycle initial voltage distribution which is projected to the end of cycle conditions based on the growth rate and the anticipated cycle operating period. The number of indications assumed in the analysis to project EOC voltage distributions, and to perform tube leak rate and burst probability analyses, is obtained by adjusting the number of reported indications to account for detection uncertainty and birth of new indications over the projection period. This is accomplished by using a Probability of Detection (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:

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

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_{repaired}	=	Number of N_i which are repaired (plugged) after the last cycle
$N_{\text{deplugged}}$	=	Number of N_i which are deplugged after the last cycle and are returned to service in accordance with IPC applicability.

There are no deplugged tubes returned to service at BOC-7B.

The methodology used in the projection of bobbin voltage frequency predictions is described in Reference 8-2, and it is essentially the same as that used in performing similar predictions during the last (EOC-6) inspection. Salient input data used for projecting EOC-7B bobbin voltage frequency are further discussed below.

6.2 Probability of Detection (POD)

The Generic Letter 95-05 (Reference 8-4) requires the application of a constant POD value of 0.6 to define the BOC distribution for the 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 may provide a more accurate prediction of voltage distributions consistent with IPC/APC experience. In addition to a constant POD of 0.6, a voltage-dependent POD developed for EPRI is also used. The EPRI POD is based on expert opinion and multiple analyst's evaluation for plants with 3/4" diameter tubes, and it represents the lower 95% confidence bound. This POD distribution is graphically illustrated in Figure 6-1.

6.3 Limiting Growth Rate Distribution

As discussed in Section 3.2, the NRC guidelines in Generic Letter 95-05 stipulate that the more conservative growth rate distributions from the past two inspections should be utilized for projecting EOC distributions for the next cycle. Since growth rates for Cycle 6 are higher than those of Cycle 7A, Cycle 6 growth rate distribution is used to develop the EOC-7B predictions. The actual growth distribution used for EOC-7B projections is a worst case hybrid growth distribution which envelopes the highest average growth on a SG basis as well as the highest growth increment during Cycle 6. This limiting growth distribution was developed during the EOC-6 inspection for projecting EOC distributions for Cycle 7A. The same conservative growth distribution was imposed on all four steam generators to provide a conservative basis for predicting EOC-7B performance. In addition, as discussed in Section 3.2, it is conservative to apply the same conservative growth rate distribution for the cold leg indications.

6.4 Cycle Operating Period

The operating periods used in the growth rate/EFPY calculations and voltage projections are:

Cycle 6	-	BOC-6 to EOC-6	- 466.4 EFPD	or	1.277 EFPY (actual)
Cycle 7A	-	BOC-7 to MOC-7	- 317.4 EFPD	or	0.869 EFPY (actual)
Cycle 7B	-	MOC-7 to EOC-7	- 116.1 EFPD	or	0.318 EFPY (estimated)

6.5 Projected EOC-7B Voltage Distribution

Calculation of the predicted EOC-7B bobbin voltage distributions was performed for all four SGs based on the EOC-7A distributions shown in Table 6-1. The

bobbin voltage distributions are shown separately for hot leg and cold leg indications in Table 6-1; since tube burst analyses need only be performed for the cold leg indications (locked TSPs constrain rupture of hot leg indications). The beginning of cycle distributions were adjusted to account for probability of detection as described above, and the adjusted number of indications at BOC-7B are also shown in Table 6-1. Calculations were performed using a constant POD of 0.6 as well as the EPRI POD distribution. A conservative hybrid growth distribution which envelopes the highest average growth rate on a SG basis as well as the largest growth rate observed for Cycle 6 operation, shown in Table 3-7, was used. The IPC voltage distributions projected for EOC-7B for all four SGs are summarized on Table 6-2. These results are also shown graphically on Figures 6-2 to 6-5. Only 8 indications were found on the cold leg side for all four SGs combined during the EOC-7A inspection, two of them were removed from service due to tube repairs, and the total at EOC-7B is projected to be about 11 for a POD of 0.6. Because of their small population, results for cold leg indications are combined with the hot leg results in Table 6-2 and Figures 6-2 to 6-5. The results based on a constant POD of 0.6 are more conservative than those using the voltage-dependent EPRI POD. Although SG-C has the largest number of indications at BOC-7B, SG-B has a few more larger indications (over 2 volts) than SG-C and, consequently, SG-B is predicted to be the limiting SG.

6.6 Comparison of Actual and Projected EOC-7A Voltage Distributions

Table 6-3, and Figures 6-6 and 6-7 provide a comparison of the EOC-7A actual measured bobbin voltage distributions with the corresponding projections performed using the last (EOC-6) inspection bobbin voltage data. EOC-7A projections based on a constant POD of 0.6 as well as the voltage-dependent EPRI POD are shown. As reported in Reference 8-5 at BOC-7A, SG-C was projected to be the limiting SG. A comparison of the actual and projected voltage distributions show that the indication population above 0.9 volts is substantially overestimated in the projections based on a constant POD of 0.6. This POD value is conservative for voltages above about 1 volt but non-conservative below 1 volt. The voltage-dependent EPRI POD shows a much better agreement with the actual measured distribution; although the projected distribution is still conservative. The conservatism in the projections for voltages above 0.9 volts using the EPRI POD is attributed to utilization of a conservative growth rate distribution that bounds the highest average voltage growth observed as well as the largest voltage growth, which occurred in different SGs.

Table 6 - 1 (Sheet 1 of 2)
Byron Unit-1 November 1995
Actual EOC-7A and Assumed BOC-7B Voltage Distributions
Used in SLB Leak Rate and Tube Burst Probability Analyses

Voltage Bin	Steam Generator A								Steam Generator B							
	EOC-7A				BOC-7B				EOC-7A				BOC-7B			
	In service		Repaired		POD = 0.6		EPRI POD		In service		Repaired		POD = 0.6		EPRI POD	
	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side
0.1	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
0.2	6	0	0	0	10.00	0.00	18.75	0.00	8	0	0	0	13.33	0.00	25.00	0.00
0.3	47	0	4	0	74.33	0.00	105.30	0.00	95	0	2	0	156.33	0.00	218.93	0.00
0.4	130	2	13	0	203.67	3.33	227.74	3.70	199	0	10	0	321.67	0.00	358.52	0.00
0.5	140	1	13	0	220.33	1.67	225.91	1.71	208	1	15	1	331.67	0.67	339.95	0.71
0.6	149	0	16	0	232.33	0.00	219.39	0.00	221	0	13	0	355.33	0.00	336.13	0.00
0.7	98	0	7	0	156.33	0.00	137.12	0.00	216	0	17	0	343.00	0.00	300.65	0.00
0.8	86	0	12	0	131.33	0.00	105.81	0.00	170	1	15	0	266.33	1.67	217.88	1.37
0.9	79	0	8	0	123.67	0.00	93.28	0.00	124	0	6	0	200.67	0.00	152.97	0.00
1	50	0	7	0	76.33	0.00	54.50	0.00	95	0	2	0	156.33	0.00	114.85	0.00
1.1	32	0	5	0	48.33	0.00	32.87	0.00	71	1	13	0	105.33	1.67	71.02	1.18
1.2	37	0	4	0	57.67	0.00	38.17	0.00	56	0	17	0	76.33	0.00	46.62	0.00
1.3	22	0	1	0	35.67	0.00	23.18	0.00	39	0	13	0	52.00	0.00	29.86	0.00
1.4	11	0	0	0	18.33	0.00	11.90	0.00	16	0	4	0	22.67	0.00	13.32	0.00
1.5	7	0	1	0	10.67	0.00	6.46	0.00	26	0	8	0	35.33	0.00	19.72	0.00
1.6	10	0	1	0	15.67	0.00	9.50	0.00	15	0	7	0	18.00	0.00	8.76	0.00
1.7	3	0	0	0	5.00	0.00	3.11	0.00	5	0	1	0	7.33	0.00	4.18	0.00
1.8	4	0	1	0	5.67	0.00	3.08	0.00	11	0	1	0	17.33	0.00	10.22	0.00
1.9	4	0	2	0	4.67	0.00	2.07	0.00	9	0	4	0	11.00	0.00	5.16	0.00
2	1	0	0	0	1.67	0.00	1.02	0.00	2	0	1	0	2.33	0.00	1.03	0.00
2.1	0	0	0	0	0.00	0.00	0.00	0.00	2	0	0	0	3.33	0.00	2.03	0.00
2.2	0	0	0	0	0.00	0.00	0.00	0.00	4	0	1	0	5.67	0.00	3.05	0.00
2.3	2	0	0	0	3.33	0.00	2.02	0.00	1	0	0	0	1.67	0.00	1.01	0.00
2.4	0	0	0	0	0.00	0.00	0.00	0.00	3	0	1	0	4.00	0.00	2.03	0.00
2.5	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
2.6	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
2.7	0	0	0	0	0.00	0.00	0.00	0.00	1	0	0	0	1.67	0.00	1.00	0.00
2.8	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
2.9	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
3	0	0	0	0	0.00	0.00	0.00	0.00	2	0	1	0	2.33	0.00	1.02	0.00
3.1	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
3.2	1	0	1	0	0.67	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
Total	919	3	96	0	1435.67	5.00	1321.18	5.41	1599	3	152	1	2513.00	4.00	2285.12	3.26
> 1V	134	0	16	0	207.33	0.00	133.38	0.00	263	1	72	0	366.33	1.67	220.24	1.18
> 2V	3	0	1	0	4.00	0	2.02	0	13	0	3	0	18.67	0.00	10.15	0.00

Table 6 - 1 (Sheet 2 of 2)
Byron Unit-1 November 1995
Actual EOC-7A and Assumed BOC-7B Voltage Distributions
Used in SLB Leak Rate and Tube Burst Probability Analyses

Voltage Bin	Steam Generator C								Steam Generator D							
	EOC-7A				BOC-7B				EOC-7A				BOC-7B			
	In service		Repaired		POD = 0.6		EPRI POD		In service		Repaired		POD = 0.6		EPRI POD	
	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side	Hot Side	Cold Side
0.1	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
0.2	13	0	0	0	21.67	0.00	40.63	0.00	8	1	3	1	10.33	0.67	22.00	2.13
0.3	71	0	0	0	118.33	0.00	165.12	0.00	88	0	25	0	121.67	0.00	179.65	0.00
0.4	157	0	3	0	258.67	0.00	287.74	0.00	144	0	31	0	209.00	0.00	235.67	0.00
0.5	251	0	3	0	415.33	0.00	425.33	0.00	121	0	23	0	178.67	0.00	183.48	0.00
0.6	224	1	5	0	368.33	1.67	348.87	1.58	126	0	33	0	177.00	0.00	166.05	0.00
0.7	214	0	8	0	348.67	0.00	306.71	0.00	109	0	35	0	146.67	0.00	125.29	0.00
0.8	171	0	4	0	281.00	0.00	230.25	0.00	70	0	21	0	95.67	0.00	74.89	0.00
0.9	129	0	6	0	209.00	0.00	159.38	0.00	62	0	20	0	83.33	0.00	59.49	0.00
1	101	0	3	0	165.33	0.00	121.23	0.00	43	0	13	0	58.67	0.00	39.89	0.00
1.1	78	0	3	0	127.00	0.00	89.31	0.00	30	0	7	0	43.00	0.00	28.50	0.00
1.2	54	0	1	0	89.00	0.00	60.54	0.00	20	0	3	0	30.33	0.00	19.79	0.00
1.3	39	0	1	0	64.00	0.00	41.86	0.00	15	0	1	0	24.00	0.00	15.48	0.00
1.4	35	0	0	0	58.33	0.00	37.88	0.00	13	0	3	0	18.67	0.00	11.07	0.00
1.5	14	0	0	0	23.33	0.00	14.93	0.00	7	0	2	0	9.67	0.00	5.46	0.00
1.6	14	0	5	0	18.33	0.00	9.71	0.00	5	0	1	0	7.33	0.00	4.25	0.00
1.7	11	0	2	0	16.33	0.00	9.39	0.00	9	0	3	0	12.00	0.00	6.32	0.00
1.8	5	0	1	0	7.33	0.00	4.10	0.00	5	0	3	0	5.33	0.00	2.10	0.00
1.9	2	0	1	0	2.33	0.00	1.04	0.00	0	0	0	0	0.00	0.00	0.00	0.00
2	3	0	3	0	2.00	0.00	0.05	0.00	3	0	0	0	5.00	0.00	3.05	0.00
2.1	2	0	0	0	3.33	0.00	2.03	0.00	1	0	0	0	1.67	0.00	1.02	0.00
2.2	2	0	0	0	3.33	0.00	2.03	0.00	1	0	1	0	0.67	0.00	0.01	0.00
2.3	0	0	0	0	0.00	0.00	0.00	0.00	1	0	0	0	1.67	0.00	1.01	0.00
2.4	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
2.5	2	0	1	0	2.33	0.00	1.02	0.00	0	0	0	0	0.00	0.00	0.00	0.00
2.6	0	0	0	0	0.00	0.00	0.00	0.00	1	0	0	0	1.67	0.00	1.01	0.00
2.7	2	0	1	0	2.33	0.00	1.01	0.00	1	0	1	0	0.67	0.00	0.00	0.00
2.8	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
2.9	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
3	0	0	0	0	0.00	0.00	0.00	0.00	2	0	1	0	2.33	0.00	1.02	0.00
3.1	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
3.2	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00
Total	1594	1	51	0	2605.67	1.67	2360.12	1.58	885	1	230	1	1245.00	0.67	1186.52	2.13
> 1V	263	0	19	0	419.33	0.00	274.87	0.00	114	0	26	0	164.00	0.00	100.10	0.00
> 2V	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00

Table 6 - 2
Byron Unit-1 November 1995
Voltage Distribution Projection for EOC - 7B
Combined Data for Hot and Cold Leg Indications

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C		Steam Generator D	
	Projected Number of Indications at EOC - 7B							
	POD 0.6	EPRI POD	POD 0.6	EPRI POD	POD 0.6	EPRI POD	POD 0.6	EPRI POD
0.1	0.04	0.08	0.06	0.10	0.09	0.17	0.04	0.09
0.2	3.87	6.94	5.84	10.14	7.99	14.34	5.24	9.39
0.3	31.21	45.03	59.96	84.87	50.86	73.99	45.80	69.43
0.4	101.87	125.12	176.41	216.57	145.99	178.35	122.31	158.07
0.5	174.25	191.99	275.86	304.22	267.79	291.03	169.40	192.71
0.6	205.86	208.29	321.14	326.13	345.15	348.09	174.67	179.75
0.7	194.50	183.90	330.11	310.61	349.96	330.96	160.02	151.31
0.8	163.95	145.94	304.59	269.50	317.05	281.35	133.35	116.86
0.9	134.25	111.37	255.95	213.55	265.82	222.47	104.62	84.98
1.0	107.24	83.69	202.14	159.49	212.97	168.81	80.24	60.79
1.1	82.46	61.26	153.69	114.65	166.06	125.47	60.81	43.66
1.2	62.89	44.75	113.00	79.84	127.31	92.47	45.64	31.39
1.3	47.71	32.73	81.77	55.05	95.99	67.41	33.96	22.66
1.4	35.26	23.63	57.87	36.97	71.22	48.52	25.24	16.38
1.5	25.40	16.63	41.58	25.10	51.60	34.30	18.86	11.88
1.6	18.06	11.63	30.16	17.70	36.48	23.60	14.19	8.58
1.7	12.96	8.22	22.70	13.02	25.39	16.07	10.84	6.41
1.8	9.47	5.94	17.32	10.00	17.57	10.88	8.40	4.91
1.9	6.98	4.36	13.64	7.83	12.22	7.50	6.49	3.80
2.0	5.13	3.20	10.69	6.22	8.63	5.26	4.95	2.93
2.1	3.80	2.37	8.41	4.96	6.25	3.83	3.78	2.21
2.2	2.78	1.76	6.68	3.94	4.64	2.84	2.87	1.69
2.3	2.04	1.32	5.19	3.10	3.54	2.16	2.21	1.30
2.4	1.54	1.00	4.09	2.44	2.78	1.71	1.75	1.05
2.5	1.14	0.75	3.20	1.96	2.25	1.37	1.44	0.84
2.6	0.85	0.59	2.54	1.57	1.85	1.15	1.22	0.71
2.7	0.69	0.51	2.10	1.34	1.59	1.04	1.10	0.68
2.8	0.65	0.53	1.88	1.31	1.45	1.02	1.11	0.77
2.9	0.65	0.55	1.74	1.23	1.39	1.04	1.06	0.70
3.0	0.60	0.48	1.48	1.05	1.27	0.97	0.91	0.57
3.1	0.50	0.37	1.24	0.89	1.05	0.79	0.76	0.47
3.2	0.40	0.00	1.05	0.71	0.84	0.61	0.62	0.31
3.3	0.33	0.00	0.79	0.53	0.64	0.45	0.47	0.00
3.4	0.04	0.70	0.60	0.27	0.48	0.09	0.31	0.70
3.5	0.00	0.00	0.43	0.00	0.21	0.00	0.00	0.00
3.6	0.70	0.30	0.00	0.00	0.00	0.70	0.70	0.00
3.7	0.00		0.00	0.70	0.70	0.00	0.00	0.30
3.8	0.00		0.70	0.00	0.00	0.30	0.00	
3.9	0.30		0.00	0.30	0.30		0.30	
4.0			0.30					
TOTAL	1440.37	1325.93	2516.90	2287.86	2607.37	2361.11	1245.68	1188.28
> 1 V	323.33	223.58	584.84	392.68	643.70	451.55	249.99	164.90
> 3 V	2.27	1.37	5.11	3.40	4.22	2.94	3.16	1.78

Table 6-3 (Sheet 1 of 2)
Byron Unit-1 November 1995
Comparison of Predicted and Actual EOC-7A Voltage Distributions

Voltage Bin	Steam Generator A			Steam Generator B			Steam Generator C			Steam Generator D		
	Number of Indications											
	EOC-7A Prediction		EOC-5B Actual	EOC-7A Prediction		EOC-5B Actual	EOC-7A Prediction		EOC-5B Actual	EOC-7A Prediction		EOC-5B Actual
	POD = 0.6	EPRI POD		POD = 0.6	EPRI POD		POD = 0.6	EPRI POD		POD = 0.6	EPRI POD	
0.1	0.02	0.04	0	0.01	0.01	0	0.00	0.00	0	0.02	0.04	0
0.2	1.50	2.55	6	0.39	0.64	8	0.17	0.23	13	1.21	2.06	5
0.3	14.43	20.55	47	4.19	5.77	95	3.62	4.74	71	8.25	11.78	21
0.4	41.77	53.06	132	17.04	20.41	199	15.62	18.43	157	25.81	32.36	89
0.5	75.80	88.78	141	43.59	47.67	209	39.88	43.65	251	50.21	57.36	141
0.6	103.31	113.22	149	80.19	82.31	221	70.89	72.81	225	69.94	75.52	145
0.7	118.14	121.74	98	114.88	111.66	216	101.24	98.62	214	80.66	82.64	144
0.8	121.64	118.60	86	138.76	128.46	171	124.43	114.90	171	82.50	80.92	136
0.9	116.80	108.37	79	148.73	131.27	124	137.27	119.89	129	78.68	73.39	111
1.0	105.30	91.94	50	145.64	122.79	95	137.46	114.42	101	69.73	62.32	88
1.1	88.92	73.46	32	132.17	105.96	72	126.20	99.83	78	57.79	49.17	63
1.2	72.16	54.98	37	111.68	84.40	56	107.20	80.28	54	45.79	36.95	36
1.3	55.58	39.35	22	89.09	63.03	39	85.78	60.16	39	34.68	26.64	36
1.4	42.40	27.15	11	68.39	44.87	16	65.65	42.72	35	25.88	18.55	19
1.5	31.30	18.73	7	50.85	31.02	26	49.17	29.26	14	19.10	12.66	13
1.6	23.37	12.87	10	36.95	20.96	15	36.09	19.42	14	13.80	8.70	5
1.7	17.42	8.85	3	26.46	14.05	5	26.39	12.88	11	10.05	6.04	7
1.8	12.68	6.05	4	18.75	9.49	11	19.53	8.61	5	7.28	4.18	4
1.9	9.38	4.12	4	13.24	6.46	9	14.64	5.87	2	5.09	2.78	2
2.0	6.89	2.76	1	9.30	4.41	2	11.05	4.09	3	3.52	1.88	1
2.1	5.45	1.90	0	6.50	2.98	2	8.34	2.90	2	2.41	1.22	0
2.2	4.20	1.29	0	4.56	2.00	4	6.22	2.03	2	1.60	0.82	1
2.3	3.26	0.88	2	3.24	1.32	1	4.67	1.42	0	1.05	0.53	0
2.4	2.59	0.58	0	2.33	0.86	3	3.41	1.00	0	0.70	0.36	1
2.5	2.06	0.40	0	1.71	0.56	0	2.59	0.67	2	0.46	0.25	0
2.6	1.54	0.26	0	1.33	0.38	0	2.02	0.47	0	0.33	0.17	0
2.7	1.28	0.20	0	1.08	0.27	1	1.55	0.34	2[#]	0.22	0.12	1[#]
2.8	1.01	0.15	0	0.87	0.20	0	1.23	0.25		0.17	0.10	
2.9	0.81	0.13	0	0.71	0.15	0	0.97	0.18		0.13	0.07	
3.0	0.69	0.11	0	0.59	0.12	2[#]	0.77	0.14		0.12	0.06	
3.1	0.55	0.09	0	0.49	0.10		0.61	0.11		0.11	0.05	
3.2	0.47	0.08	1[#]	0.40	0.09		0.50	0.10		0.12	0.05	
3.3	0.43	0.08		0.34	0.08		0.40	0.09		0.11	0.05	
3.4	0.39	0.07		0.28	0.08		0.34	0.08		0.12	0.05	
3.5	0.34	0.08		0.24	0.08		0.29	0.08		0.12	0.05	
3.6	0.31	0.07		0.20	0.08		0.26	0.07		0.12	0.05	
3.7	0.28	0.07		0.17	0.08		0.25	0.07		0.12	0.05	
3.8	0.26	0.07		0.16	0.07		0.23	0.07		0.12	0.04	
3.9	0.25	0.07		0.14	0.08		0.22	0.07		0.12	0.05	
4.0	0.23	0.08		0.14	0.08		0.23	0.07		0.12	0.06	

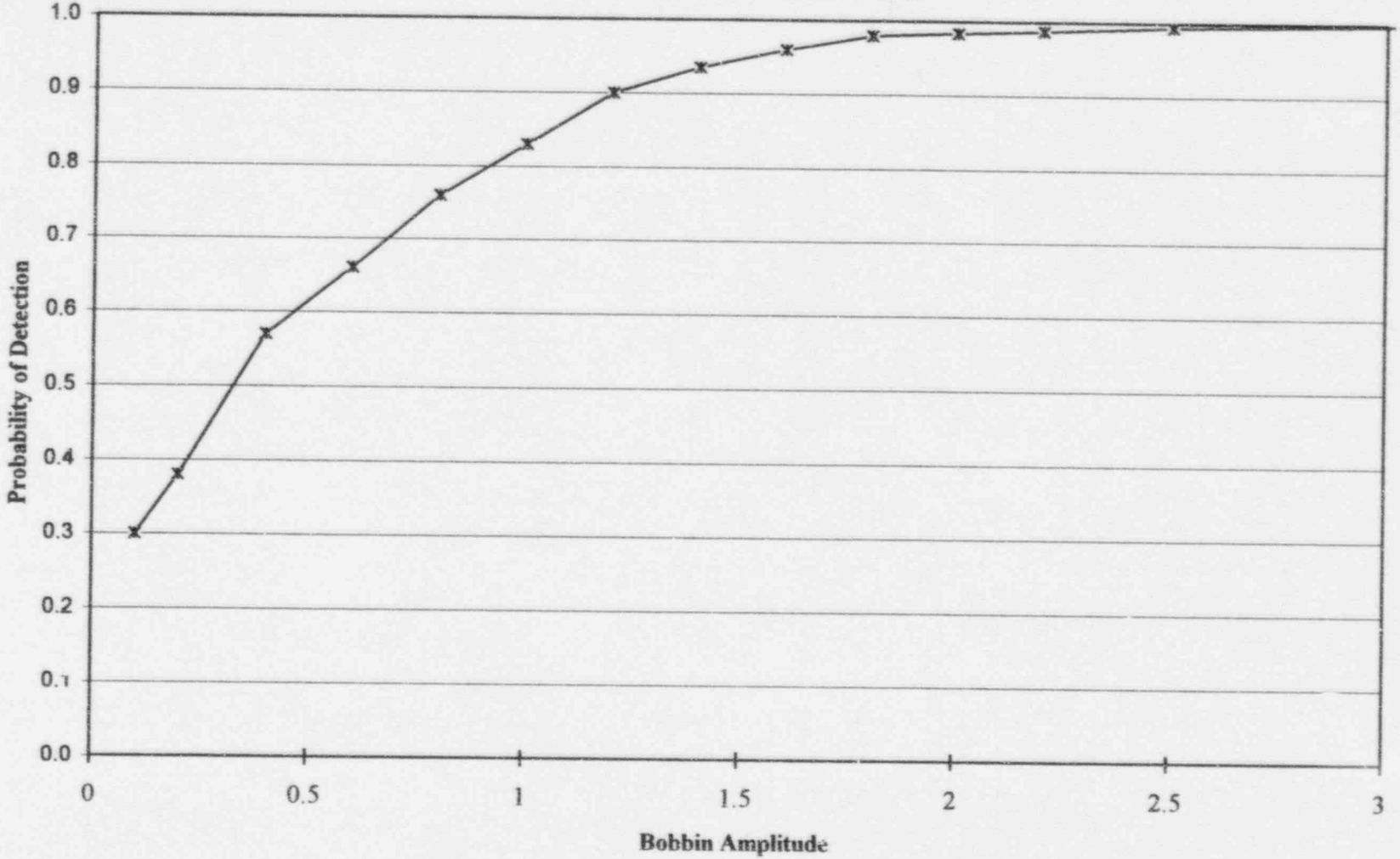
Table continues on the next page

[#] Bin with the largest indication found in the steam generator

Table 6-3 (Sheet 2 of 2)
Byron Unit-1 November 1995
Comparison of Predicted and Actual EOC-7A Voltage Distributions

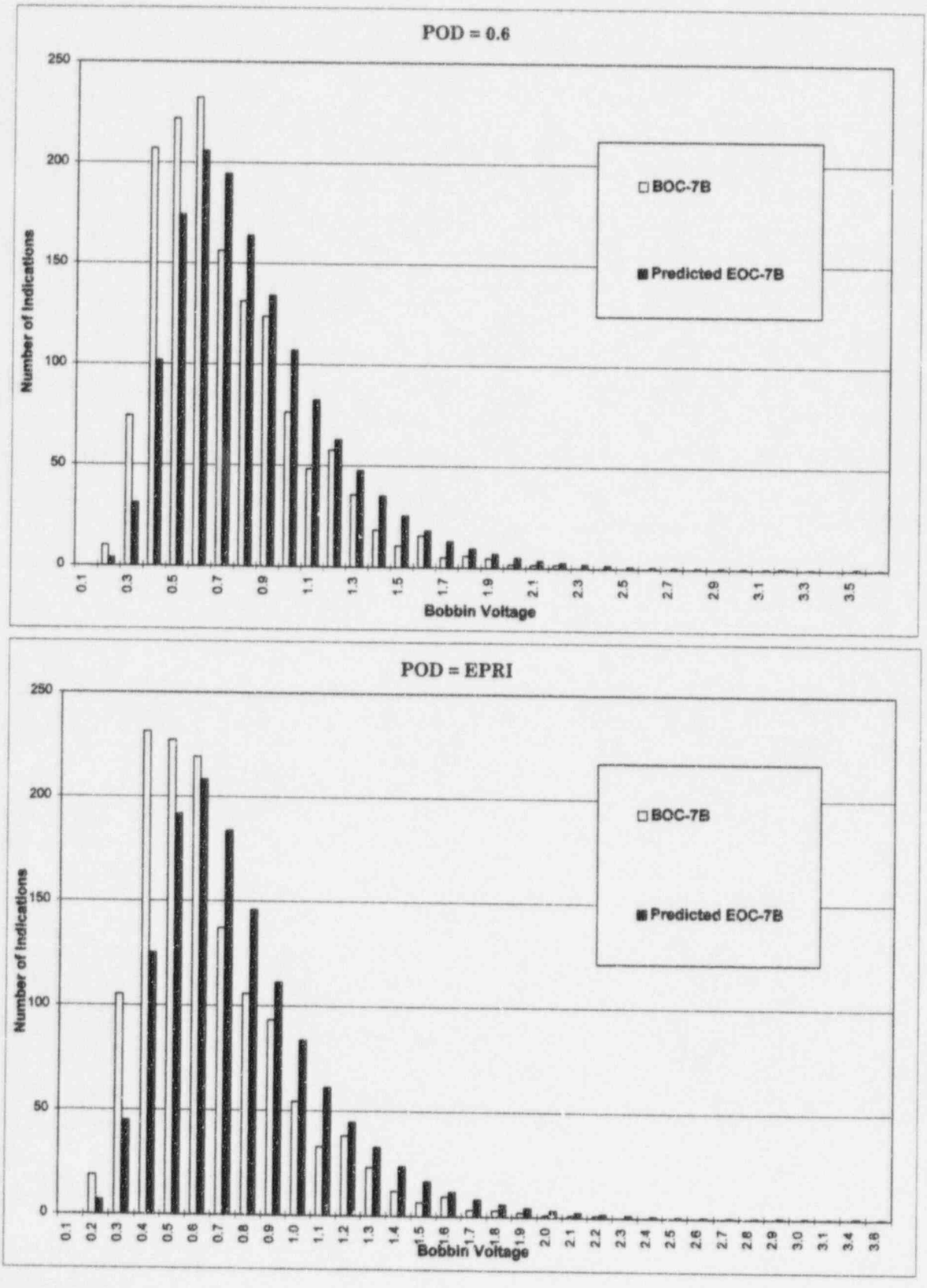
Voltage Bin	Steam Generator A			Steam Generator B			Steam Generator C			Steam Generator D		
	Number of Indications											
	EOC-7A Prediction		EOC-5B Actual	EOC-7A Prediction		EOC-5B Actual	EOC-7A Prediction		EOC-5B Actual	EOC-7A Prediction		EOC-5B Actual
	POD = 0.6	EPRI POD		POD = 0.6	EPRI POD		POD = 0.6	EPRI POD		POD = 0.6	EPRI POD	
4.1	0.23	0.12		0.15	0.09		0.23	0.08		0.14	0.08	
4.2	0.27	0.16		0.17	0.12		0.23	0.11		0.16	0.11	
4.3	0.31	0.21		0.22	0.17		0.25	0.15		0.20	0.14	
4.4	0.32	0.24		0.27	0.21		0.28	0.19		0.21	0.16	
4.5	0.33	0.26		0.31	0.25		0.31	0.22		0.22	0.17	
4.6	0.31	0.26		0.35	0.27		0.34	0.24		0.22	0.17	
4.7	0.34	0.26		0.37	0.28		0.35	0.26		0.23	0.17	
4.8	0.31	0.25		0.38	0.28		0.34	0.26		0.21	0.17	
4.9	0.28	0.23		0.37	0.27		0.34	0.25		0.21	0.16	
5.0	0.25	0.21		0.35	0.25		0.31	0.23		0.17	0.13	
5.1	0.22	0.17		0.32	0.23		0.29	0.21		0.15	0.11	
5.2	0.16	0.14		0.29	0.19		0.25	0.18		0.13	0.10	
5.3	0.17	0.11		0.24	0.16		0.22	0.15		0.11	0.08	
5.4	0.12	0.09		0.21	0.13		0.18	0.12		0.09	0.07	
5.5	0.12	0.08		0.17	0.10		0.15	0.10		0.08	0.05	
5.6	0.10	0.07		0.15	0.09		0.13	0.08		0.06	0.05	
5.7	0.09	0.06		0.12	0.08		0.11	0.07		0.06	0.05	
5.8	0.08	0.06		0.11	0.07		0.10	0.06		0.05	0.04	
5.9	0.07	0.06		0.10	0.07		0.09	0.06		0.05	0.04	
6.0	0.13	0.06		0.09	0.06		0.09	0.06		0.04	0.04	
6.1	0.14	0.06		0.09	0.06		0.08	0.06		0.05	0.04	
6.2	0.17	0.06		0.08	0.06		0.09	0.05		0.04	0.03	
6.3	0.14	0.06		0.08	0.06		0.07	0.06		0.04	0.04	
6.4	0.12	0.05		0.08	0.06		0.08	0.06		0.04	0.04	
6.5	0.11	0.06		0.08	0.06		0.07	0.05		0.03	0.04	
6.6	0.12	0.05		0.08	0.06		0.07	0.06		0.04	0.04	
6.7	0.09	0.06		0.07	0.06		0.07	0.05		0.04	0.04	
6.8	0.07	0.06		0.08	0.06		0.07	0.05		0.04	0.04	
6.9	0.09	0.06		0.07	0.06		0.08	0.05		0.04	0.05	
7.0	0.13	0.10		0.09	0.07		0.08	0.06		0.06	0.00	
7.1	0.19	0.22		0.12	0.12		0.12	0.11		0.03	0.00	
7.2	0.34	0.15		0.19	0.19		0.19	0.17		0.00	0.00	
7.3	0.32	0.00		0.28	0.26		0.24	0.17		0.00	0.70	
7.4	0.33	0.70		0.29	0.03		0.26	0.00		0.70	0.00	
7.5	0.26	0.00		0.13	0.00		0.26	0.00		0.00	0.00	
7.6	0.21	0.00		0.00	0.70		0.24	0.70		0.00	0.30	
7.7	0.22	0.30		0.70	0.00		0.20	0.00		0.30		
7.8	0.19			0.00	0.30		0.12	0.30				
7.9	0.01			0.30			0.00					
8.0	0.00						0.00					
8.1	0.70						0.00					
8.6	0.00						0.70					
8.8	0.30						0.00					
11.7							0.30					
TOTAL	1093.67	978.92	922	1283.33	1050.88	1602	1215.36	966.10	1595	702.62	653.59	1069
> 1 V	394.96	260.07	131	589.91	399.89	264	584.78	378.41	263	235.61	175.20	189
> 3 V	11.97	5.85	1	10.11	6.40	0	11.31	5.89	0	5.44	3.95	0

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



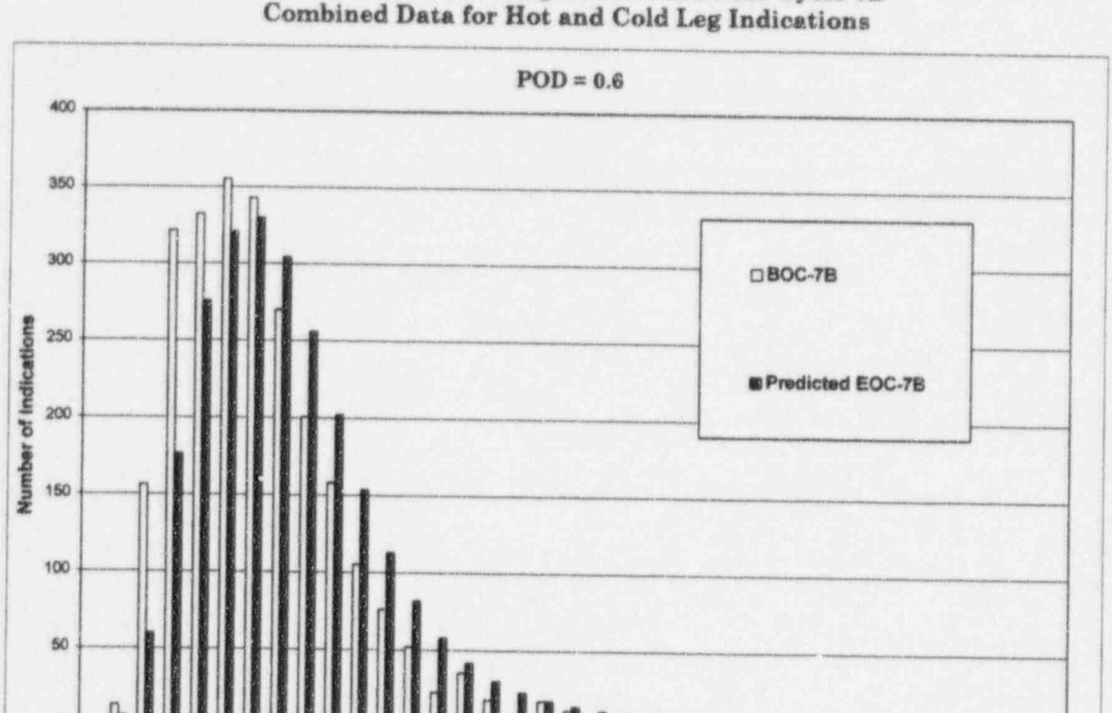
CAE90DAY.XLS|Fig6-1|3/1/96|2:35 PM

Figure 6 - 2
Byron Unit-1 SG A
Predicted Bobbin Voltage Distribution for Cycle 7B
Combined Data for Hot and Cold Leg Indications



PREDCOMP.XLS Fig6-2 3/1/96 4:31 PM

Figure 6 - 3
Byron Unit-1 SG B
Predicted Bobbin Voltage Distribution for Cycle 7B
Combined Data for Hot and Cold Leg Indications



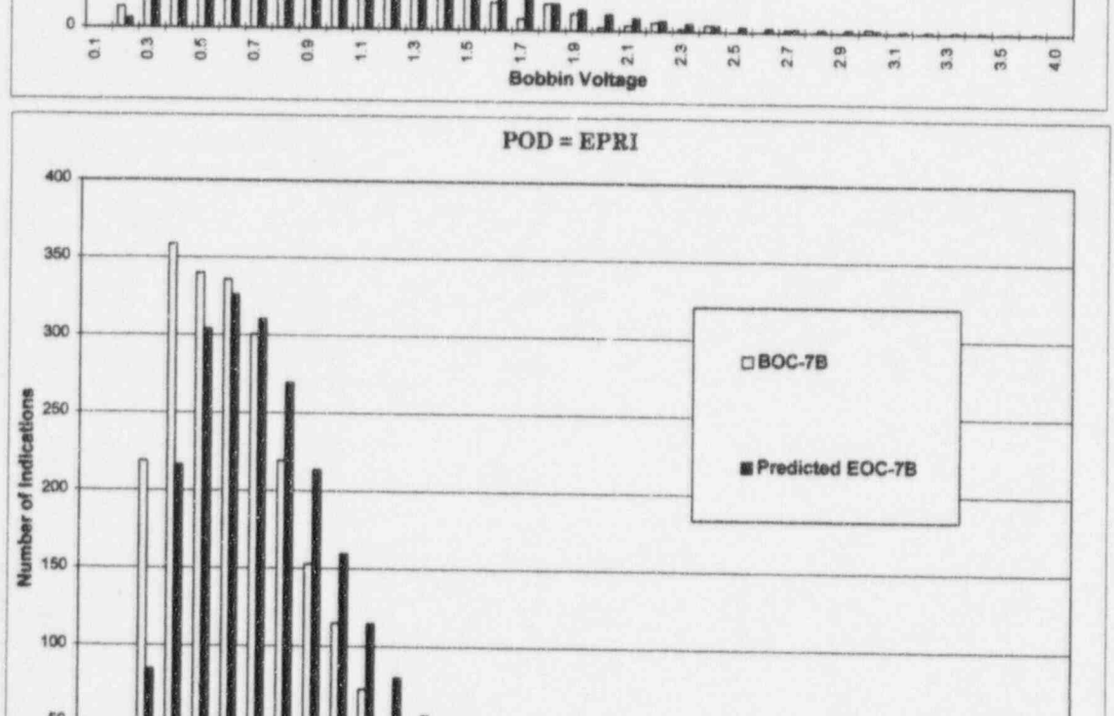


Figure 6-4
Byron Unit-1 SG C
Predicted Bobbin Voltage Distribution for Cycle 7B
Combined Data for Hot and Cold Leg Indications

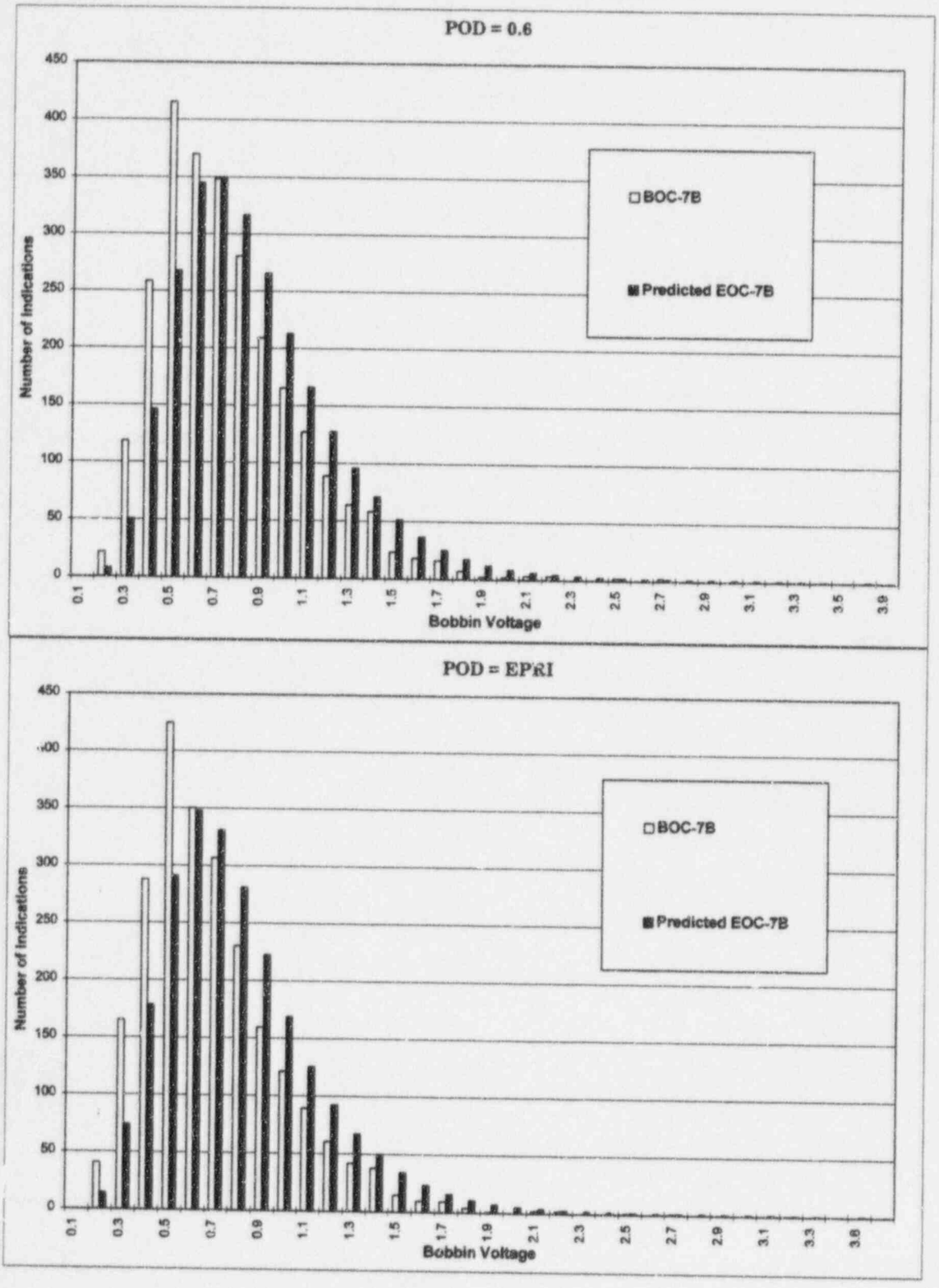


Figure 6 - 5
Byron Unit-1 SG D
Predicted Bobbin Voltage Distribution for Cycle 7B
Combined Data for Hot and Cold Leg Indications

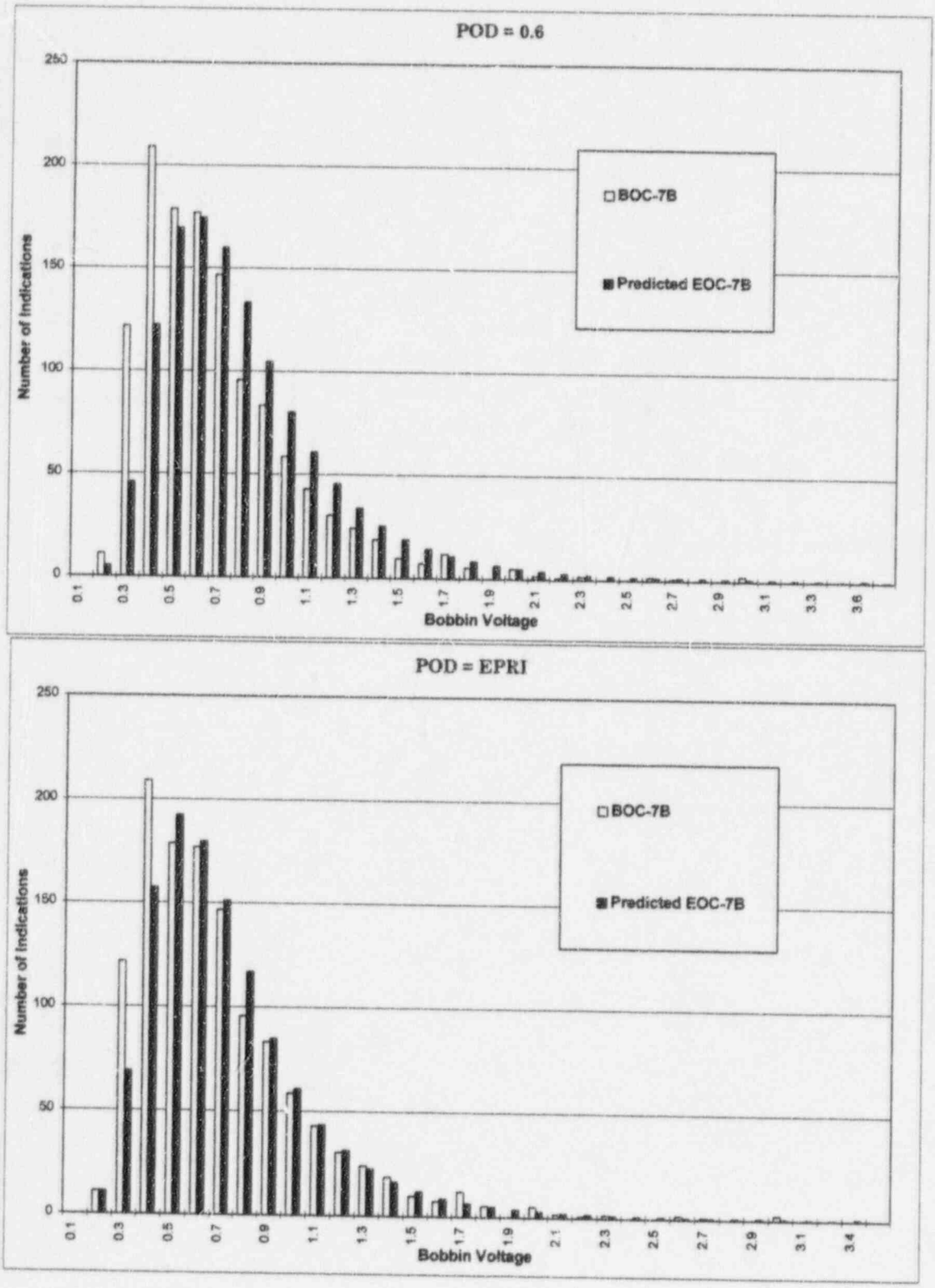
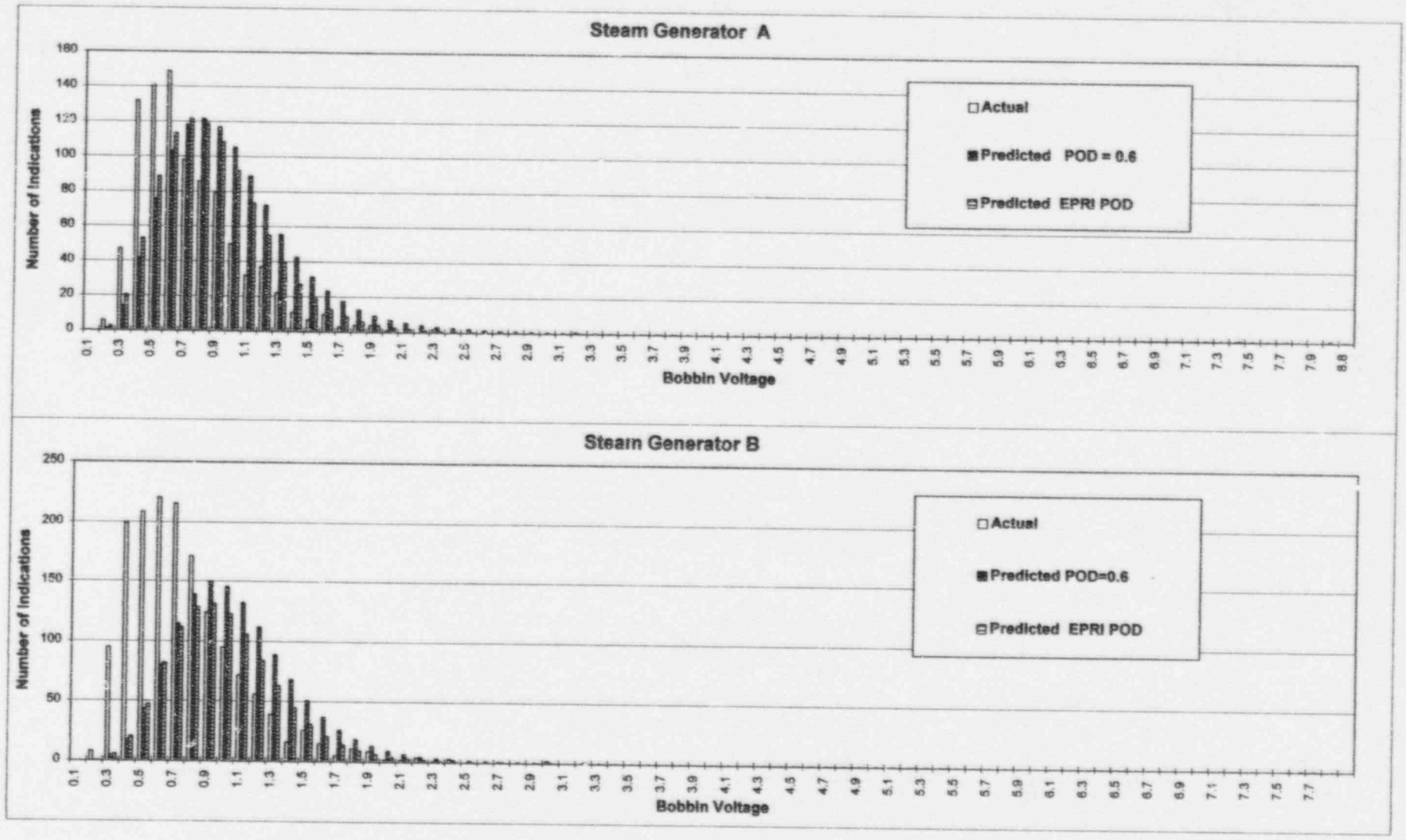
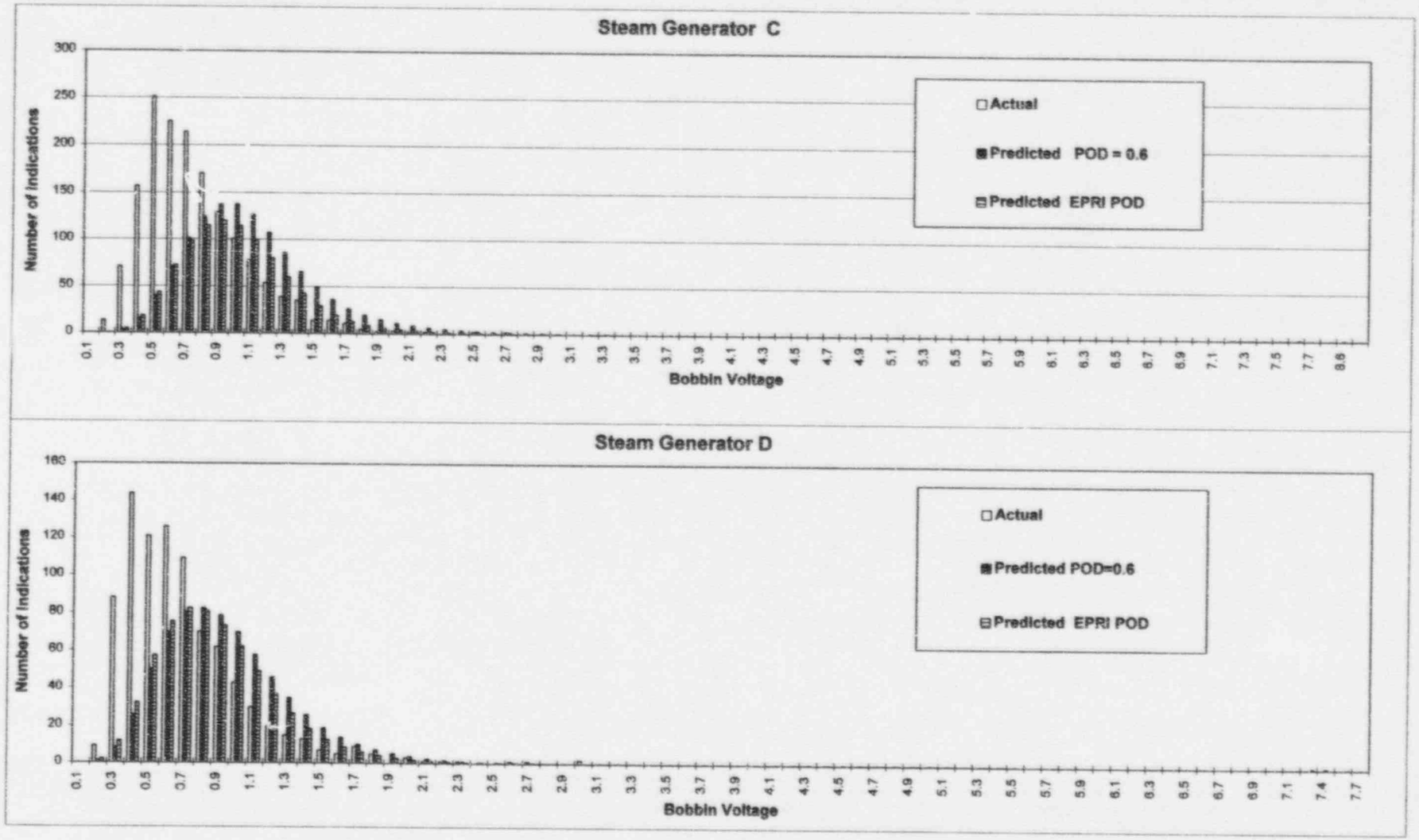


Figure 6 - 6
Byron Unit-1 November 1995
Bobbin Voltage Distributions for Cycle 7-A



PREDCOMP.XLS Fig6-6 3/1/96 5:33 PM

Figure 6 - 7
Byron Unit-1 November 1995
Bobbin Voltage Distributions for Cycle 7-A



PREDCOMP XLS Fig6-7 3/1/96 5:34 PM

7.0 SLB Leak Rate and Tube Burst Probability Analyses

This section presents results of analyses carried out to predict leak rates and tube burst probabilities for postulated SLB conditions using the actual voltage distributions from EOC-7A inspection as well as for the projected EOC-7B voltage distributions. The methodology used in these analyses is described in Section 5.0. For the TSP locked condition during Cycle 7B (to support a 3 volt IPC), analyses were performed separately for the indication population on the hot leg and cold leg sides of each generator since only indications on the cold leg are to be considered for tube burst probability analysis. As discussed in Section 6.5, although SG-C has the largest number of indications on the hot leg side, SG-B is expected to yield the limiting SLB leak rate for Cycle 7B since it has a few more larger (over 2 volts) indications returned to service than SG-C (10 in SG-B vs 6 in SG-C, see Table 6-1) and the SLB leak rate is primarily dependent on the larger indications. SG-A with the largest number of indications on the cold leg side is expected to be limiting from the tube burst probability standpoint.

7.1 Leak Rate and Tube Burst Probability for EOC-7A

Analyses to calculate EOC-7A SLB leak rate and tube burst probabilities were performed using the actual bobbin voltage distributions presented in Table 3-1 (all indications together) and Table 6-1 (separately for hot leg and cold leg indications). These analyses considered both conditions prior to and after TSP locking (for application of a 3 volt IPC). Results of Monte Carlo calculations are summarized on Table 7-1. Free span analyses (without TSP locking) are the reference analyses for Cycle 7A and their results are to be compared with the allowable limits.

The report prepared for the last (EOC-6) inspection, Reference 8-5, contains EOC-7A projections only for the limiting SG, which is SG-C. Leak rate and burst probability projections for EOC-7A were performed for all four SGs during this outage to enable comparison of results based on actual measured bobbin voltage distributions with those projected using the prior inspection data. Comparison of the EOC-7A actuals with the corresponding predictions indicates that:

a) For a POD of 0.6 SG-C was predicted to be the most limiting steam generator for EOC-7A based on a voltage distribution projection performed during the EOC-6 inspection. However, SG-B was predicted to be the limiting steam generator for EOC-7A for the EPRI POD.

b) SG-B was determined to have the highest tube leak rate and tube burst probability based on actual EC bobbin measurements for EOC-7A, although the absolute differences in the results for SG-B and SG-C are small.

c) The leak rate and tube burst probability predictions for the projected EOC-7A indication population distribution, based on the EOC-6 inspection data,

are very conservative for all four SGs compared to the corresponding values calculated using actual measured bobbin measurements for EOC-7A (by a factor of at least 14). The large differences between projections and actuals are attributable to a reduction in voltage growth. Figures 6-5 and 6-6 show the actual and projected EOC-7A bobbin distributions used in the leak rate and burst analyses. The projected indication population based on EPRI POD being greater than the measured population above 0.9 volts indicates that the actual growth rates in Cycle 7A were below the growth rates assumed for projections (Cycle 6 rates). A comparison of Cycle 6 and Cycle 7A growth data shown in Figure 3-6 and Table 3-3 confirms this. The use of a constant POD of 0.6, per the GL 95-05 requirement, results in further overestimation of indication population in higher voltage bins, and consequently, introduces additional conservatism in the results.

d) The leak rate and tube burst probability predictions for all four SG's based EOC-7A bobbin measurements are well within the allowable limits.

e) With TSP's locked, tube burst probability decreases by more than two orders of magnitude.

f) The effect of indications restrained from burst on the SLB leak rate compared to free span analysis is negligible due to the low free span tube burst probability for the actual distributions.

In summary, the free span SLB leak rate and tube burst probability calculated using the actual EOC-7A bobbin voltage distributions for all four SGs are far below the corresponding projections assuming a voltage distribution based on the NRC SER endorsed probability of detection of 0.6 (by at least a factor of 14). Limiting values for SLB leak rate (0.075 gpm) and tube burst probability (1.3×10^{-3}) were calculated for SG-B. These results are much lower than the allowable Cycle 7A SLB leakage limit of 12.5 gpm and the NRC reporting guideline of 10^{-2} for the tube burst probability. The major impact of restraining indications on the hot leg side from bursting is to decrease the tube burst probability by over two orders of magnitude.

7.2 Leak Rate and Tube Burst Probability for EOC-7B

Calculations to predict the performance of the limiting steam generator in Byron Unit-1 at EOC-7B conditions were carried out using two values for POD: 1) NRC required constant value of 0.6, 2) voltage dependent EPRI POD distribution. The methodology used in these predictions is the same as previously described for EOC-7A. Results of the EOC-7B predictions are summarized on Table 7-2. With a constant POD of 0.6, the projected limiting EOC-7B SLB leak rate is 0.25 gpm and

it is predicted for SG-B. The tube burst probability for all four SGs are below 4.0×10^{-6}. These limiting values are much lower than the allowable SLB leakage limit for Cycle 7B of 12.5 gpm and the NRC reporting guideline of 10^{-2} for the tube burst probability.

Table 7-1

Byron Unit-1 1995 EOC- 7A 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 - 7A PROJECTIONS Based on EOC-6 Inspection Data [2]							
A		0.6	1094	8.8	2.58×10^{-2}	5.53×10^{-4}	2.50
		EPRI	979	7.7	1.12×10^{-2}	4.07×10^{-4}	1.22
B		0.6	1283	7.9	2.01×10^{-2}	3.33×10^{-4}	1.94
		EPRI	1051	7.8	1.48×10^{-2}	1.04×10^{-4}	1.44
C		0.6	1215	11.7	3.94×10^{-2}	8.85×10^{-4}	3.69
		EPRI	966	7.8	1.33×10^{-2}	2.08×10^{-4}	1.29
D		0.6	703	7.7	9.17×10^{-3}	$< 4.0\times10^{-6}$	0.95
		EPRI	654	7.6	9.28×10^{-3}	1.90×10^{-5}	0.87
EOC - 7A ACTUAL (Free Span - With Displaced Tube Support Plates)							
A		1	922	3.5	1.07×10^{-3}	$< 4\times10^{-6}$	0.060
B		1	1602	3.5	1.30×10^{-3}	$< 4\times10^{-6}$	0.075
C		1	1595	3.2	5.33×10^{-4}	$< 4\times10^{-6}$	0.064
D		1	886	3.5	6.49×10^{-4}	$< 4\times10^{-6}$	0.056
EOC - 7A ACTUAL (Tube Support Plates Assumed Locked)							
A	Hot Side	1	919	3.5	Negligible[3]	Negligible[3]	0.060
	Cold Side	1	3	0.7	$< 4\times10^{-6}$	$< 4\times10^{-6}$	1×10^{-4}
	Total	-	922	3.5	$< 4\times10^{-6}$	$< 4\times10^{-6}$	0.06
B	Hot Side	1	1599	3.5	Negligible[3]	Negligible[3]	0.075
	Cold Side	1	3	1.3	1.90×10^{-5}	$< 4\times10^{-6}$	1×10^{-4}
	Total	-	1602	3.5	1.90×10^{-5}	$< 4\times10^{-6}$	0.075
C	Hot Side	1	1594	3.2	Negligible[3]	Negligible[3]	0.064
	Cold Side	1	1	0.8	$< 4\times10^{-6}$	$< 4\times10^{-6}$	1×10^{-4}
	Total	-	1595	3.2	$< 4\times10^{-6}$	$< 4\times10^{-6}$	0.064
D	Hot Side	1	885	3.5	Negligible[3]	Negligible[3]	0.056
	Cold Side	1	1	0.4	$< 4\times10^{-6}$	$< 4\times10^{-6}$	1×10^{-4}
	Total	-	886	3.5	$< 4\times10^{-6}$	$< 4\times10^{-6}$	0.056

Notes:
1 Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
2 Based on actual Cycle 7A duration of 317.4 EFPD.
3 Below 10^{-10} (Reference 7-4)

Table 7-2
Byron Unit-1 November 1995 Outage
Summary of Projected Tube Leak Rate and Burst Probability
for EOC-7B - 250k Simulations

Steam Generator		POD	No. of Indications[1]	Max. Volts[2]	Burst Probability		SLB Leak Rate gpm
					1 Tube	2 Tubes	
EOC - 7B PROJECTIONS							
A	Hot Side	0.6	1436	3.9	Negligible[3]	Negligible[3]	0.11
	Cold Side	0.6	5	0.8	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}-0.02
	Total	0.6	1441	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.11
A	Hot Side	EPRI	1321	3.6	Negligible[3]	Negligible[3]	0.07
	Cold Side	EPRI	5	0.8	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}
	Total	EPRI	1326	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.07
B	Hot Side	0.6	2513	4.0	Negligible[3]	Negligible[3]	0.25
	Cold Side	0.6	4	1.5	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}
	Total	0.6	2517	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.25
B	Hot Side	EPRI	2285	3.9	Negligible[3]	Negligible[3]	0.16
	Cold Side	EPRI	3	1.4	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}
	Total	EPRI	2288	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.16
C	Hot Side	0.6	2606	3.9	Negligible[3]	Negligible[3]	0.21
	Cold Side	0.6	2	~ 1	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}
	Total	0.6	2608	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.21
C	Hot Side	EPRI	2360	3.8	Negligible[3]	Negligible[3]	0.14
	Cold Side	EPRI	2	~ 1	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}
	Total	EPRI	2362	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.14
D	Hot Side	0.6	1245	3.9	Negligible[3]	Negligible[3]	0.14
	Cold Side	0.6	1	~0.5	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}
	Total	0.6	1246	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.14
D	Hot Side	EPRI	1186	3.7	Negligible[3]	Negligible[3]	0.01
	Cold Side	EPRI	2	0.5	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1×10^{-4}
	Total	EPRI	1188	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.01

Notes
(1) Number of indications adjusted for POD.
(2) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
(3) Below 10^{-10} (Reference 8-6)

8.0 References

8.1 WCAP-14047, "Braidwood Unit 1 Technical Support for Cycle 5 Steam Generator Interim Plugging Criteria", Westinghouse Nuclear Service Division.

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

8.3 Westinghouse Report SG-95-01-003, "Byron Unit-1 End-of-Cycle 6 Interim Plugging Criteria Report," Westinghouse Nuclear Service Division, January 1995.

8.4 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.

8.5 Westinghouse Report SG-95-06-005, "Braidwood Unit-1, 1995 Interim Plugging Criteria 90 Day Report," Westinghouse Nuclear Service Division, June 1995.

9.6 WCAP-14273, "Technical Support for Alternate Plugging Criteria with Tube Expansion at Tube Support Plate Intersections for Braidwood-1 and Byron-1 Model D Steam Generators," Westinghouse Nuclear Service Division, February 1995.

9.7 Westinghouse Report NSD-SGD-1187, "Byron Unit-1, Interim Plugging Criteria Return to Power Report," Westinghouse Nuclear Service Division, December 1995.