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BRAIDWOOD UNIT - 1

CYCLE 6 INTERIM PLUGGING CRITERIA 90 DAY REPORT

February 1996

Westinghouse Electric Corporation
Energy Systems Business Unit
Nuclear Services Division
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Braidwood Unit-1

Cycle 6 Interim Plugging Criteria 90 Day Report

1.0 Introduction

This report provides the Braidwood Unit-1 steam generator tube Eddy Current (EC) inspection results at the end of Cycle 5* 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 5B) and the ongoing cycle (Cycle 6). Analyses for Cycle 5B were carried out using the actual bobbin voltage distributions measured during the EOC-5B outage, and the results compared with the corresponding values from projections performed during the last (EOC-5A) outage. The analyses for Cycle 5B considered conditions both before and after tube support plate (TSP) locking (to support a 3 volt IPC). However, since the EOC-5B 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 6) based on the 3.0 volt repair criteria. Those analyses utilized bobbin voltage distributions and growth rates measured during the EOC-5B inspection. The methodology used in these evaluations is in accordance with previously published Westinghouse reports (References 8.1, 8.2 and 8.6)

*Since there was a mid-cycle inspection in February '95, for clarity the first-half of Cycle 5 is referred to as Cycle 5A and the second-half as Cycle 5B.

2.0 Summary and Conclusions

SLB leak rate and tube burst probability analyses were performed for the actual EOC-5B EC bobbin voltage distributions as well as the projected EOC-6 bobbin voltage distributions. Results for the EOC-5B actual conditions are considerably lower than the corresponding projections, performed during the EOC-5A outage using a probability of detection of 0.6, by at least a factor of 4.8. As with the earlier projections, SG C was found to be the limiting SG at actual EOC-5B voltage distributions. The leak rate and tube burst probability projections at EOC conditions for the current cycle (Cycle 6) are also well within acceptable limits, with SG C again being the limiting SG for leak.

For the actual EOC-5B bobbin voltage distribution, free span SLB leak rate (applicable prior to TSP locking) and tube burst probability are calculated to be 0.07 gpm and 6.49×10^{-4}, respectively, for the limiting SG which is SG C; these values are below the corresponding BOC-5B projections for SG C assuming a voltage distribution adjusted using the NRC SER endorsed probability of detection of 0.6. Also, these values are much lower than the allowable Cycle 5B SLB leakage limit of 9.1 gpm and the NRC reporting guideline of 10^{-2} for the conditional tube burst probability. The corresponding EOC-5B values calculated for a locked TSP condition are 0.07 gpm leak rate and a burst probability of less than 4×10^{-6}. Leak rate is not significantly affected by the locked TSP condition due to the low free span burst probability (i.e., only a few indications restrained from burst, IRBs, would have yielded a higher leakage even if there was no TSP restraint). As expected, the tube burst probability is substantially reduced for the locked TSP condition. The allowable leakage limit for Cycle 6 has been increased to 26.8 gpm, so the leakage margin is even higher at the BOC-6.

Limiting SLB leak rate projected for the EOC-6 conditions (locked TSPs) using the NRC SER endorsed probability of detection of 0.6 is 6.99 gpm. This value is projected for SG C and it is well below the allowable EOC-6 leakage limit of 26.8 gpm. The limiting tube burst probability is projected for SG A, and its magnitude is 6.81×10^{-4} which is well below the NRC reporting guideline of 10^{-2}. SG A has a higher EOC-6 tube burst probability than SG C since more cold leg indications were detected in it (11) than in SG C (1) during the current inspection. The projected EOC-6 leak rate and burst probability are higher than found at the actual EOC-5B condition due to the requirement to use the limiting growth rate distribution (Cycle 5A values) over the last two operating cycles for the projections. The burst probability is dominated by the cold leg indications (no TSP locking in cold leg) utilizing the larger Cycle 5A growth rates.

A total of 4136 indications were found in the EOC-5B inspection of which 327 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 of the hot leg indications above 3 volts), and 200 were confirmed as flaws by the RPC inspection. The RPC

confirmed indications included 178 above 1.0 volt. SG C had 1480 bobbin indications, of which 301 were above 1.0 volt, 83 of these were inspected by RPC and 46 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-5B Inspection Results and Voltage Growth Rates

3.1 EOC-5B Inspection Results

In accordance with the IPC guidance provided by the NRC Generic Letter 95-05, the end of Cycle 5B inspection of the Braidwood 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. Also, a single indication was found above 1 volt on the cold leg side, but no degradation was detected during RPC inspection.

In addition, an augmented RPC inspection was 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 25 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 eddy current results at EOC-5B. 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. A further separation of data in Table 3-1 into hot and cold leg indications is given in Section 6. The indications that remain active for Cycle 6 operation is the difference between the observed and the plugged. Overall, the combined data for all four steam generators of Braidwood Unit-1 shows that:

- Out of a total of 4136 indications identified during the inspection, a total of 4083 indications are being returned to service for Cycle 6.

- Of the 4136 indications, a total of 327 were RPC inspected.

- Of the 327 RPC inspected, a total of 200 were RPC confirmed.

- A total of 53 indications were removed from service. Consistent with the new 3 volt IPC, hot leg indications with bobbin amplitude of less than or equal to 3.0 volts and cold leg indications less than or equal to 1 volt are not removed from service. Only one indication was repaired due to ODSCC at TSP intersections.

A review of Table 3-1 indicates that SG C has more and higher voltage BOC-6 indications (a quantity of 1480, with 301 indications above 1.0 volt) than SG A, B or D, it potentially will be the limiting SG at EOC-6. However, SG A had the largest indication (3.17 volts) found in the EOC-5B inspection. Figure 3-1 shows the actual bobbin voltage distribution determined from the EOC-5B EC inspection; Figure 3-2 shows the distribution of those EOC-5B indications which were plugged and taken out of service; Figure 3-3 shows the indications which are being returned to service for Cycle 6. Of the 53 indications removed from service, 38 indications were in tubes plugged for degradation mechanisms other than ODSCC at TSP's. Among the 15 ODSCC indications removed from service, only one indication was above the 3 volt IPC limit, and the remaining 14 indications were in tubes near the wedge supports for which TSP IPC does not apply.

The distribution of EOC-5B indications as a function of support plate 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 (3909 out of 4136 indications occurred at the first three hot leg TSP intersections), although the mechanism extended to higher TSPs. Only 18 indications were detected on the cold leg side. This distribution indicates the predominant temperature dependence of ODSCC at Braidwood 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 6 operation, voltage growth rates were developed from the EOC-5B (October 1995) inspection data and a reevaluation of the same indications from the EOC-5A (February 1995) inspection EC signals. Table 3-3 shows the cumulative probability distribution for growth rate of each Braidwood Unit-1 steam generator during Cycle 5B (3/95 - 9/95) on an EFPY basis. This data is also plotted in Figure 3-5. Among the four steam generators, SG A has the indication with the largest voltage growth as well as a slightly larger average voltage growth during Cycle 5B. Average growth rates for each SG during Cycle 5B are summarized in Table 3-4. The average growth rates over the entire voltage range vary between 30% and 42% (of the BOC voltage) per EFPY, between SGs, with an overall average of 34% per EFPY. The average growth for indications greater than or equal to 0.75 volt is 28% per EFPY and for indications less than 0.75 volt it is 40% per EFPY. SG C had the highest average voltage at BOC-5B whereas SG A had the largest average

voltage growth during Cycle 5B. This was found to be true during the last (EOC-5A) inspection also.

Averaged composite voltage growth data from all four steam generators for the last four operating periods (4/91 - 9/92, 10/92 - 3/94, 5/94 - 2/95 and 3/95 - 9/95) are summarized in Table 3-5. Figure 3-6 provides a comparison of the growth rate distributions for the last three operating periods. Growth rates for Cycle 5B are significantly below those observed for the preceding three operating periods. Furthermore, except for Cycle 5A operating period, growth rates show a strong downward trend from the BOC-3.

Table 3-6 lists the largest growth rates above 1 volt, in descending order, that were developed during Cycle 5B. All but one indication shown are new indications and they were RPC confirmed. The EOC-5A voltages used to estimate growth rates for new indications were obtained by revaluating last inspection data. The largest TSP ODSCC indication detected during the inspection, 3.17 volts in SG A, does not appear in Table 3-6 because its estimated growth rate is below 1 volt. This indication was not reported in the last inspection possibly due to a noisy signal.

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 5A are higher than those of Cycle 5B. Therefore, Cycle 5A growth rates are used to develop the EOC-6 predictions. The actual growth distribution used for EOC-6 projection is a worst case hybrid growth distribution that was developed during the last inspection (EOC-5A) and applied to project EOC-5B voltage distributions. This limiting growth rate distribution envelopes the actual EOC-5A distribution with the simultaneous limitations of SG A (highest average growth) and of SG C (highest growth increment of 5.7 volts during Cycle 5A). Table 3-7 compares this hybrid growth distribution with the growth distributions observed for SG A and SG C during Cycle-5B. It is evident that the hybrid growth distribution is more conservative than the Cycle 5B growth rate distribution. This conservative growth distribution was imposed on all four steam generators, to provide a conservative basis for predicting EOC-6 performance.

3.3 NDE Uncertainties

The NDE uncertainties applied for the Cycle 5B 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. 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-6 voltage distributions.

Table 3-1 (1 of 2)
Braidwood Unit -1 October 1995 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 5B

Voltage Bin	Steam Generator A					Steam Generator B					Steam Generator C				
	In-Service During Cycle 5B				BOC - 6	In-Service During Cycle 5B				BOC - 6	In-Service During Cycle 5B				BOC - 6
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications Returned to Service
0.1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
0.2	3	0	0	0	3	2	0	0	0	2	7	0	0	0	7
0.3	50	1	0	0	50	10	0	0	0	10	25	1	0	1	24
0.4	105	3	1	1	104	65	1	1	0	65	122	1	0	1	121
0.5	139	2	2	3	136	60	1	0	0	60	168	5	1	1	167
0.6	144	3	2	3	141	95	0	0	0	95	164	3	2	3	161
0.7	117	4	3	5	112	68	0	0	0	68	199	3	0	3	196
0.8	115	1	0	1	114	63	1	0	1	62	200	5	1	3	197
0.9	104	1	1	2	102	52	1	1	0	52	164	3	2	2	162
1	66	2	1	2	64	53	2	1	0	53	129	1	0	2	127
1.1	67	9	5	1	66	25	25	16	0	25	107	8	5	0	107
1.2	45	4	2	0	45	28	25	11	0	28	71	8	5	1	70
1.3	24	2	1	0	24	12	12	9	0	12	36	9	5	0	36
1.4	16	3	2	0	16	7	7	3	0	7	28	12	4	1	27
1.5	8	6	5	0	8	5	4	1	0	5	25	14	7	0	25
1.6	8	8	7	1	7	2	2	1	1	1	8	7	4	0	8
1.7	4	2	2	0	4	3	3	2	0	3	7	7	4	0	7
1.8	7	7	6	1	6	2	2	1	0	2	5	5	3	0	5
1.9	1	1	1	0	1	0	0	0	0	0	4	3	2	0	4
2	3	2	1	0	3	3	3	3	0	3	1	1	0	0	1
2.1	2	2	1	0	2	1	1	0	0	1	3	3	2	0	3
2.2	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1
2.3	0	0	0	0	0	0	0	0	0	0	3	3	2	1	2
2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
2.7	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
2.8	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1
3	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1
3.2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Total	1031	66	45	21	1010	556	90	50	2	554	1480	105	52	19	1461
> 1V	188	49	35	4	184	88	84	47	1	87	301	83	46	3	298

Table 3 - 1 (2 of 2)
Braidwood Unit -1 October 1995 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 5B

Voltage Bin	Steam Generator D					Composite of All 4 SGs				
	In-Service During Cycle 5B				BOC - 6	In-Service During Cycle 5B				BOC - 6
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications Returned to Service
0.1	0	0	0	0	0	1	0	0	0	1
0.2	5	1	0	0	5	17	1	0	0	17
0.3	21	1	0	0	21	106	3	0	1	105
0.4	89	0	0	0	89	381	5	2	2	379
0.5	141	0	0	1	140	508	8	3	5	503
0.6	145	3	1	3	142	548	9	5	9	539
0.7	144	3	1	1	143	528	10	4	9	519
0.8	136	2	1	2	134	514	9	2	7	507
0.9	111	1	0	1	110	431	6	4	5	426
1	88	0	0	1	87	336	5	2	5	331
1.1	63	3	3	0	63	262	45	29	1	261
1.2	36	7	6	0	36	180	44	24	1	179
1.3	36	9	8	2	34	108	32	23	2	106
1.4	19	4	2	0	19	70	26	11	1	69
1.5	13	10	10	0	13	51	34	23	0	51
1.6	5	5	5	0	5	23	22	17	2	21
1.7	7	7	6	0	7	21	19	14	0	21
1.8	4	4	4	0	4	18	18	14	1	17
1.9	2	2	2	0	2	7	6	5	0	7
2	1	1	1	0	1	8	7	5	0	8
2.1	0	0	0	0	0	6	6	3	0	6
2.2	1	1	1	0	1	2	2	2	0	2
2.3	0	0	0	0	0	3	3	2	1	2
2.4	1	1	1	0	1	1	1	1	0	1
2.5	0	0	0	0	0	1	1	1	0	1
2.7	1	1	1	0	1	2	2	1	0	2
2.8	0	0	0	0	0	1	1	1	0	1
3	0	0	0	0	0	1	1	1	0	1
3.2	0	0	0	0	0	1	1	1	1	0
Total	1069	66	53	11	1058	4136	327	200	53	4083
> 1V	189	55	50	2	187	766	271	178	10	756

Table 3 -2
Braidwood Unit-1 October 1995 Outage
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 5B

Tube Support Plate	Steam Generator A				Steam Generator B				Composite of All Four SGs			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
3H	504	2.64	0.74	0.12	276	2.03	0.76	0.08	2207	2.94	0.78	0.11
5H	325	3.17	0.72	0.13	224	1.93	0.72	0.15	1250	3.17	0.72	0.11
7H	124	1.76	0.74	0.15	37	1.63	0.70	0.13	452	2.73	0.73	0.12
8H	56	2.04	0.69	0.13	10	1	0.57	0.17	152	2.04	0.64	0.12
9H	5	1.27	0.65	0.14	3	0.4	0.34	0.01	46	1.85	0.66	0.12
10H	5	0.58	0.47	0.04	1	0.3	0.30	0.04	9	0.59	0.46	0.07
11H	1	0.57	0.57	0.06	0	-	-	-	2	0.72	0.65	0.13
11C	3	1.01	0.90	0.07	3	0.65	0.47	0.03	6	1.01	0.68	0.05
10C	6	0.53	0.37	0.03	1	0.42	0.42	0.01	9	0.53	0.38	0.03
9C	1	0.39	0.39	0.08	0	-	-	-	1	0.39	0.39	0.08
8C	1	0.3	0.30	0.02	0	-	-	-	1	0.3	0.30	0.02
5C	0	-	-	-	1	0.39	0.39	-0.02	1	0.39	0.39	-0.02
Total	1031				556				4136			

Tube Support Plate	Steam Generator C				Steam Generator D			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth	Number of Indicstions	Maximum Voltage	Average Voltage	Average Growth
3H	856	2.94	0.82	0.11	571	2.64	0.77	0.11
5H	397	2.3	0.70	0.08	304	1.84	0.73	0.10
7H	175	2.73	0.73	0.11	116	2.33	0.74	0.12
8H	39	1.1	0.59	0.08	47	1.48	0.63	0.12
9H	12	1.85	0.67	0.16	26	1.45	0.69	0.10
10H	0	-	-	-	3	0.59	0.50	0.13
11H	0	-	-	-	1	0.72	0.72	0.20
11C	0	-	-	-	0	-	-	-
10C	1	0.46	0.46	0.07	1	0.32	0.32	-0.01
9C	0	-	-	-	0	-	-	-
8C	0	-	-	-	0	-	-	-
5C	0	-	-	-	0	-	-	-
Total	1480				1069			

Table 3 - 3
Braidwood Unit-1
Signal Growth Statistics For Cycle 5B on an EFPY Basis

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C		Steam Generator D		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-1.7	0	0	0	0	1	0.001	0	0	1	0.0002
-1	0	0	0	0	1	0.001	0	0	1	0.0005
-0.8	0	0	0	0	0	0.001	1	0.001	1	0.0007
-0.7	0	0	0	0	0	0.001	1	0.002	1	0.0010
-0.6	0	0	1	0.002	0	0.001	1	0.003	2	0.0015
-0.5	0	0	0	0.002	2	0.003	2	0.005	4	0.0024
-0.4	1	0.001	3	0.007	0	0.003	6	0.010	10	0.0048
-0.3	6	0.007	2	0.011	9	0.009	8	0.018	25	0.0109
-0.2	18	0.024	13	0.034	33	0.031	11	0.028	75	0.0290
-0.1	40	0.063	26	0.081	84	0.088	40	0.065	190	0.0750
0	122	0.181	82	0.228	164	0.199	163	0.218	531	0.2033
0.1	200	0.375	95	0.399	299	0.401	230	0.433	824	0.4026
0.2	191	0.561	93	0.567	306	0.607	193	0.614	783	0.5919
0.3	128	0.685	85	0.719	248	0.775	125	0.731	586	0.7336
0.4	91	0.773	57	0.822	122	0.857	99	0.823	369	0.8228
0.5	69	0.840	31	0.878	68	0.903	63	0.882	231	0.8786
0.6	50	0.888	22	0.917	47	0.935	32	0.912	151	0.9151
0.7	35	0.922	12	0.939	21	0.949	20	0.931	88	0.9364
0.8	23	0.945	12	0.960	19	0.962	20	0.949	74	0.9543
0.9	17	0.961	4	0.968	17	0.974	12	0.961	50	0.9664
1	10	0.971	4	0.975	11	0.981	13	0.973	38	0.9756
1.1	5	0.976	4	0.982	7	0.986	5	0.978	21	0.9807
1.2	8	0.984	2	0.986	5	0.989	6	0.983	21	0.9857
1.3	4	0.987	1	0.987	3	0.991	5	0.988	13	0.9889
1.4	4	0.991	1	0.989	2	0.993	3	0.991	10	0.9913
1.5	1	0.992	0	0.989	0	0.993	1	0.992	2	0.9918
1.6	1	0.993	2	0.993	4	0.995	2	0.993	9	0.9940
1.7	0	0.993	0	0.993	2	0.997	3	0.996	5	0.9952
1.8	0	0.993	1	0.995	0	0.997	1	0.997	2	0.9956
1.9	2	0.995	1	0.996	0	0.997	0	0.997	3	0.9964
2	2	0.997	1	0.998	0	0.997	0	0.997	3	0.9971
2.1	1	0.998	1	1.0	0	0.997	1	0.998	3	0.9978
2.3	0	0.998	0		1	0.997	0	0.998	1	0.9981
2.6	0	0.998	0		1	0.998	0	0.998	1	0.9983
2.7	0	0.998	0		1	0.999	0	0.998	1	0.9985
2.9	0	0.998	0		0	0.999	1	0.999	1	0.9988
3	1	0.999	0		0	0.999	0	0.999	1	0.9990
3.5	0	0.999	0		1	0.999	1	1.0	2	0.9995
4.1	0	0.999	0		1	1	0		1	0.9998
4.2	1	1.0	0		0		0		1	1.0
Total	1031		556		1480		1069		4136	

Table 3-4
Braidwood Unit -1 October 1995 Outage
Average Voltage Growth During Cycle 5B

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	4136	0.64	0.110	0.218	17.3%	34.2%
V_{BOC} < .75 Volts	2831	0.49	0.100	0.199	20.3%	40.2%
≥ .75 Volts	1305	0.94	0.131	0.260	13.9%	27.5%
	Steam Generator A					
Entire Voltage Range	1031	0.60	0.127	0.251	21.2%	41.9%
V_{BOC} < .75 Volts	759	0.48	0.113	0.223	23.7%	46.8%
≥ .75 Volts	272	0.94	0.166	0.328	17.7%	35.0%
	Steam Generator B					
Entire Voltage Range	556	0.62	0.110	0.217	17.8%	35.1%
V_{BOC} < .75 Volts	392	0.47	0.114	0.225	24.1%	47.6%
≥ .75 Volts	164	0.97	0.100	0.198	10.4%	20.5%
	Steam Generator C					
Entire Voltage Range	1480	0.67	0.101	0.199	15.0%	29.6%
V_{BOC} < .75 Volts	951	0.51	0.090	0.178	17.5%	34.7%
≥ .75 Volts	529	0.95	0.120	0.236	12.5%	24.8%
	Steam Generator D					
Entire Voltage Range	1069	0.64	0.108	0.213	17.0%	33.6%
V_{BOC} < .75 Volts	729	0.50	0.094	0.186	18.8%	37.2%
≥ .75 Volts	340	0.93	0.137	0.271	14.8%	29.3%

Based on Cycle 5B duration of 0.506 EFPY

Table 3-5
Braidwood Unit-1 October 1995 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 5B (3/95 - 9/95) - 0.506 EFPY					
Entire Voltage Range	4136	0.64	0.110	0.218	17.3%	34.2%
V_{BOC} < .75 Volts	2831	0.49	0.100	0.199	20.3%	40.2%
≥ .75 Volts	1305	0.94	0.131	0.260	13.9%	27.5%
	Cycle 5A (5/94 - 2/95) - 0.714 EFPY					
Entire Voltage Range	3884	0.56	0.284	0.398	51.1%	71.6%
V_{BOC} < .75 Volts	3085	0.46	0.25	0.35	53.8%	75.4%
≥ .75 Volts	799	0.92	0.420	0.588	45.8%	64.1%
	Cycle 4 (10/92 - 3/94) - 1.147 EFPY					
Entire Voltage Range	2654	0.48	0.260	0.227	54.2%	47.2%
V_{BOC} < .75 Volts	2289	0.41	0.290	0.253	70.7%	61.7%
≥ .75 Volts	365	0.92	0.130	0.113	14.1%	12.3%
	Cycle 3 (4/91 - 9/92) - 1.132 EFPY					
Entire Voltage Range	167	0.62	0.620	0.554	100.0%	89.3%
V_{BOC} < .75 Volts	145	0.43	0.650	0.580	151.2%	135.0%
≥ .75 Volts	22	0.92	0.420	0.375	45.7%	40.8%

Table 3 - 6
Braidwood Unit-1 October 1995
Summary of Largest Voltage Growth Rates for BOC-5B to EOC-5B

Steam Generator				Bobbin Voltage			RPC	New
SG	Row	Col	Elevation	EOC-5B	BOC-5B	Growth	Confirmed ?	Indication ?
A	4	71	3H	2.45	0.36	2.09	Yes	Yes
C	13	73	3H	2.94	1	1.94	Yes	Yes
D	15	7	3H	2.64	0.88	1.76	Yes	Yes
C	20	55	7H	2.73	0.99	1.74	Yes	Yes
A	20	65	5H	1.78	0.27	1.51	Yes	Yes
D	25	67	7H	2.33	0.91	1.42	Yes	Yes
C	16	46	3H	2.29	0.95	1.34	Yes	Yes
C	11	108	7H	2.19	0.92	1.27	Yes	Yes
C	22	34	3H	2.05	0.9	1.15	Yes	Yes
A	5	64	3H	1.98	0.92	1.06	NT*	No
D	13	102	7H	1.89	0.85	1.04	Yes	Yes
B	18	102	5H	1.17	0.14	1.03	Yes	Yes
B	15	44	3H	1.99	0.98	1.01	Yes	Yes

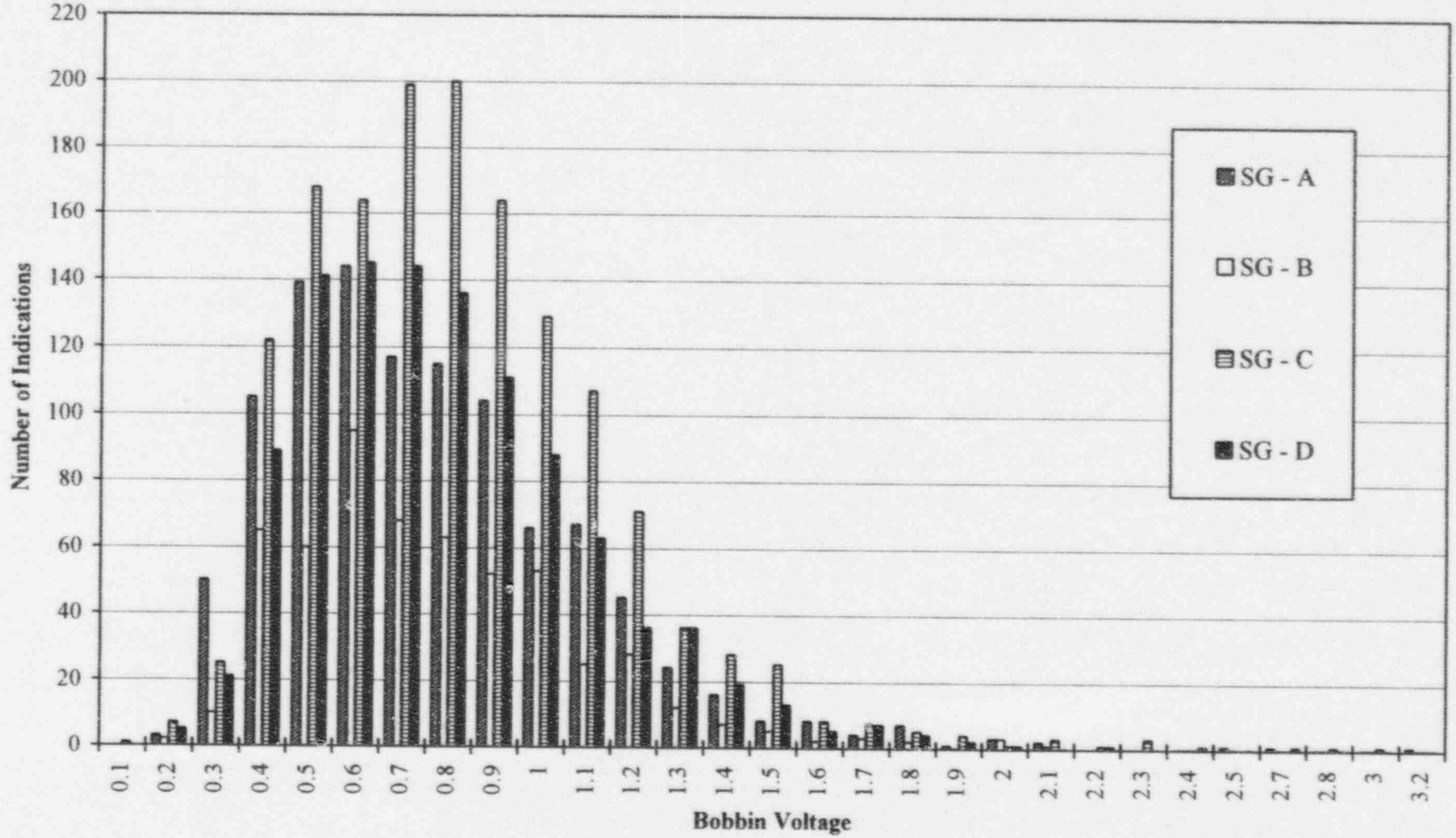
* Not RPC tested

Table 3 - 7
Braidwood Unit-1
Signal Growth Statistics (on an EFPY Basis) Assumed for Limiting Case Projections

Delta Volts	Cycle 5B				Cycle 5A	
	Steam Generator A		Steam Generator C		Hybrid#	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-1.7	0		1	0.001	0	
-1	0		1	0.001	0	
-0.8	0		0	0.001	0	
-0.7	0		0	0.001	0	
-0.6	0		0	0.001	0	
-0.5	0		2	0.003	0	
-0.4	1	0.001	0	0.003	2	0.0019
-0.3	6	0.007	9	0.009	6	0.0077
-0.2	18	0.024	33	0.031	11	0.0183
-0.1	40	0.063	84	0.088	48	0.0644
0	122	0.181	164	0.199	144	0.2029
0.1	200	0.375	299	0.401	138	0.3356
0.2	191	0.561	306	0.607	156	0.4856
0.3	128	0.685	248	0.775	107	0.5885
0.4	91	0.773	122	0.857	92	0.6769
0.5	69	0.840	68	0.903	72	0.7462
0.6	50	0.888	47	0.935	48	0.7923
0.7	35	0.922	21	0.949	48	0.8385
0.8	23	0.945	19	0.962	39	0.8760
0.9	17	0.961	17	0.974	17	0.8923
1	10	0.971	11	0.981	18	0.9096
1.1	5	0.976	7	0.986	21	0.9298
1.2	8	0.984	5	0.989	13	0.9423
1.3	4	0.987	3	0.991	11	0.9529
1.4	4	0.991	2	0.993	9	0.9615
1.5	1	0.992	0	0.993	7	0.9683
1.6	1	0.993	4	0.995	4	0.9721
1.7	0	0.993	2	0.997	5	0.9769
1.8	0	0.993	0	0.997	0	0.9769
1.9	2	0.995	0	0.997	6	0.9827
2	2	0.997	0	0.997	1	0.9837
2.1	1	0.998	0	0.997	4	0.9875
2.2	0	0.998	0	0.997	0	0.9875
2.3	0	0.998	1	0.997	1	0.9885
2.4	0	0.998	0	0.997	3	0.9913
2.5	0	0.998	0	0.997	1	0.9923
2.6	0	0.998	1	0.998	0	0.9923
2.7	0	0.998	1	0.999	1	0.9933
2.8	0	0.998	0	0.999	0	0.9933
2.9	0	0.998	0	0.999	0	0.9933
3	1	0.999	0	0.999	2	0.9952
3.1	0	0.999	0	0.999	0	0.9952
3.2	0	0.999	0	0.999	1	0.9962
3.4	0	0.999	0	0.999	1	0.9971
3.5	0	0.999	1	0.999	0	0.9971
3.7	0	0.999	0	0.999	1	0.9981
4.1	0	0.999	1	1.0	1	0.9990
4.2	1	1.0	0		1	0.9990
5.7	0		0		1	1.0
Total	1031		1480		1041	

Cycle 5A steam generator A distribution plus the largest growth for steam generator C. This hybrid growth distribution was also used to project EOC-5B voltage distribution during the last (EOC-5A) outage.

Figure 3 - 1
Braidwood Unit -1 October 1995 Outage
Bobbin Voltage Distributions for Tubes in Service During Cycle 5B



BOBNRPC.XLSFig_3-1]

Figure 3 - 2
Braidwood Unit -1 October 1995 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 5B Service

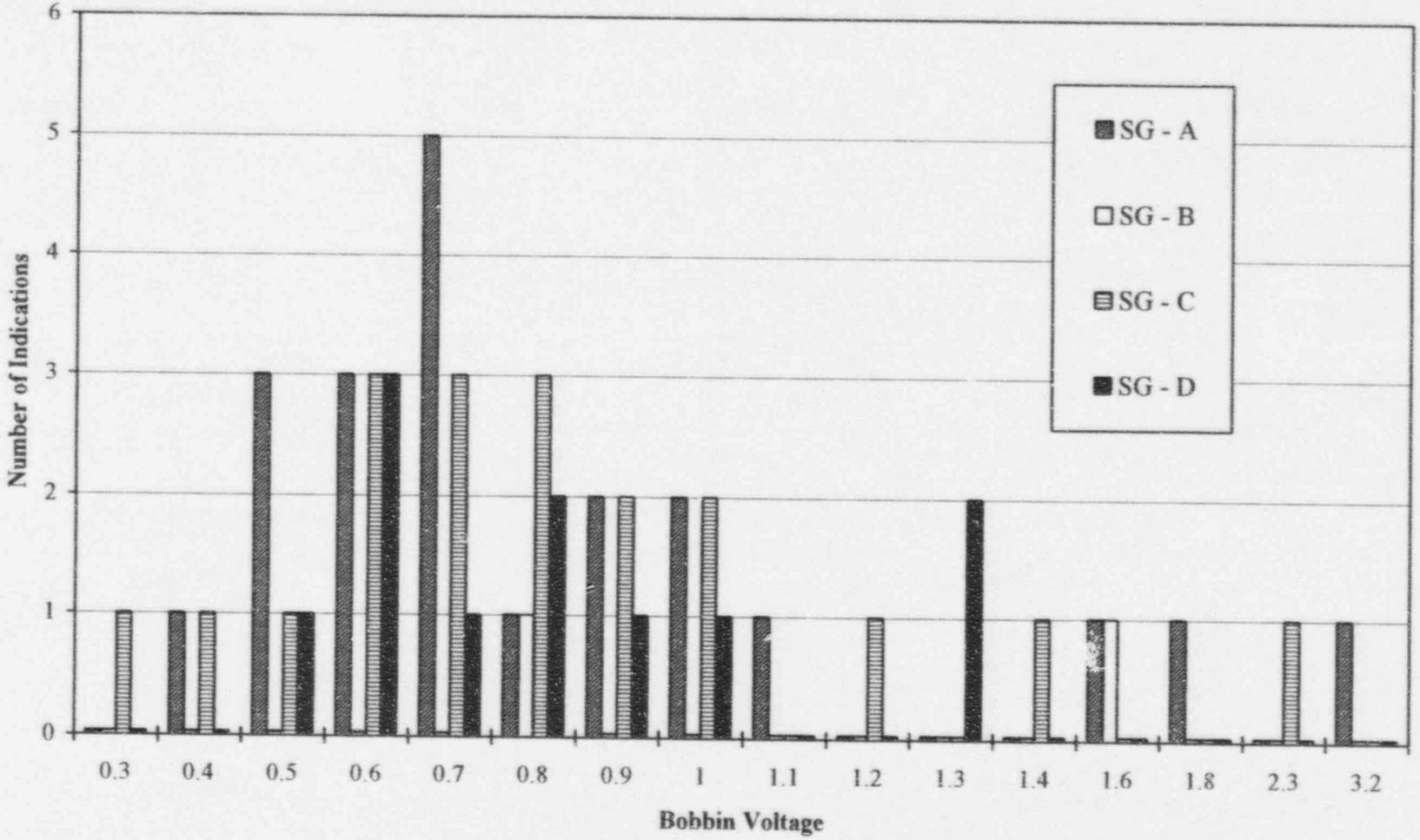
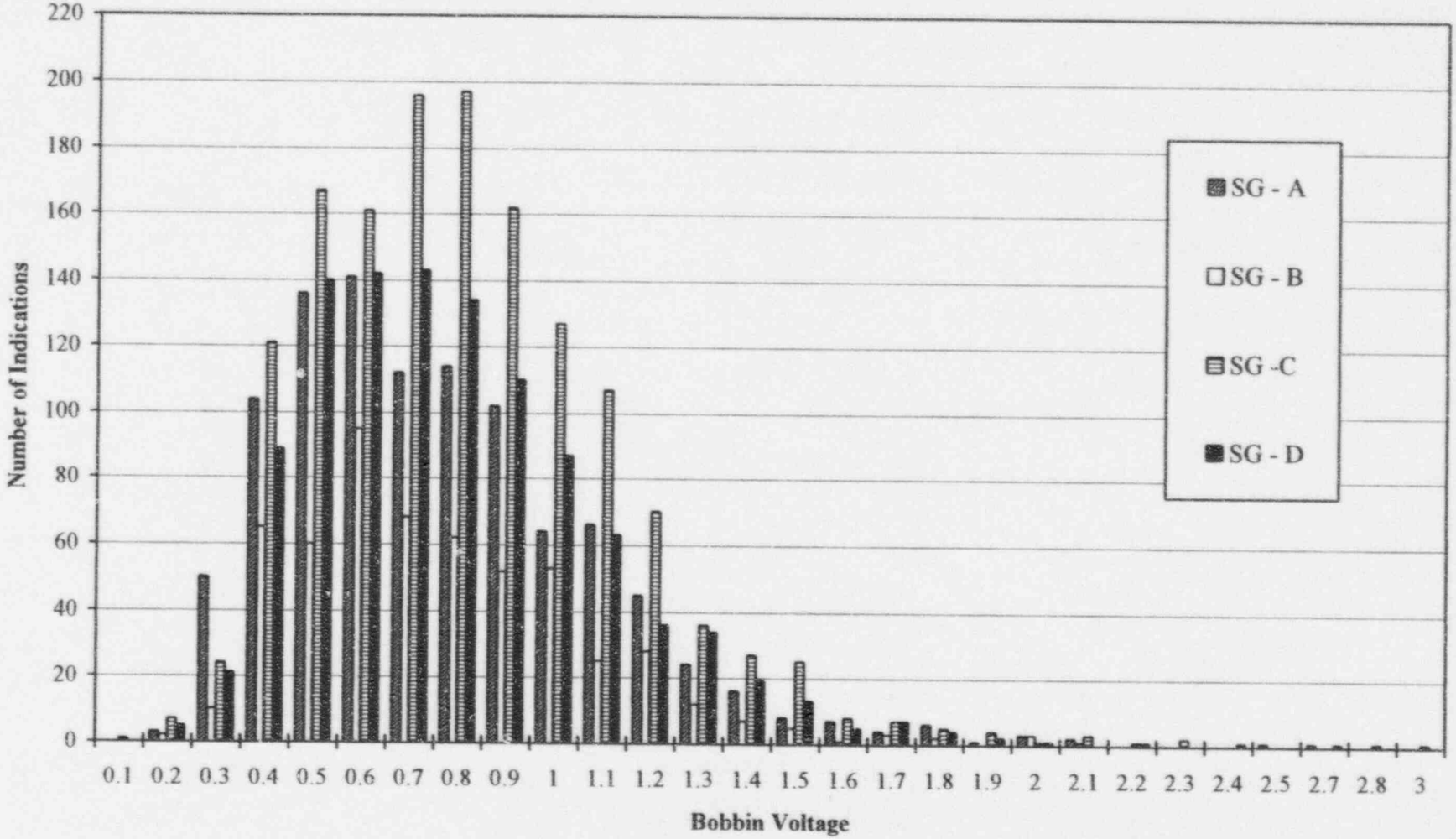


Figure 3 - 3
Braidwood Unit -1 October 1995 Outage
Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 6



BOBNRPC.XLSFig. 3-3

Figure 3 - 4
Braidwood Unit-1 October 1995 Outage
ODSCC Axial Distributions for Tubes in Service During Cycle 5B

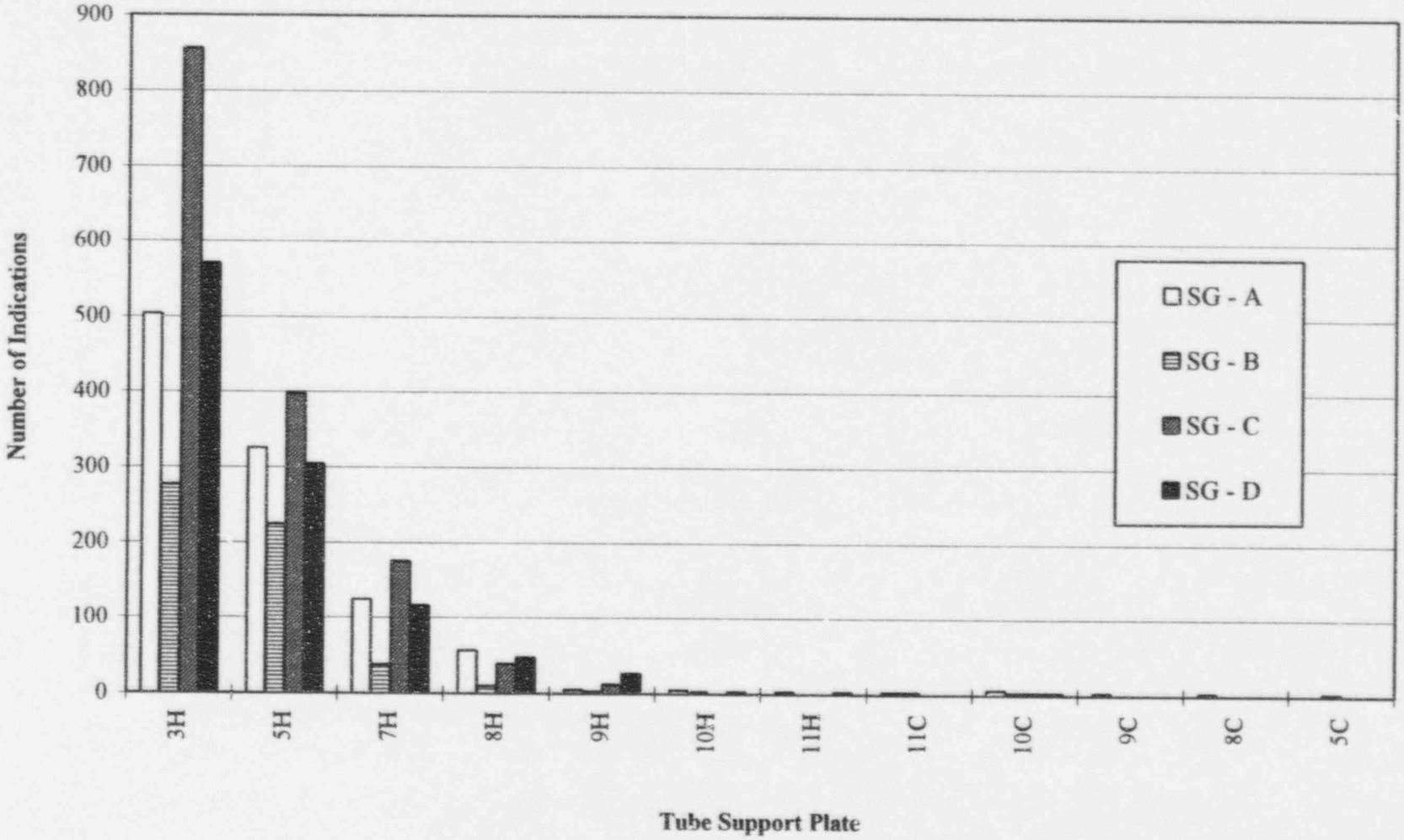


Figure 3 - 5
Braidwood Unit -1 Cycle 5B (April '95 to October '95)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

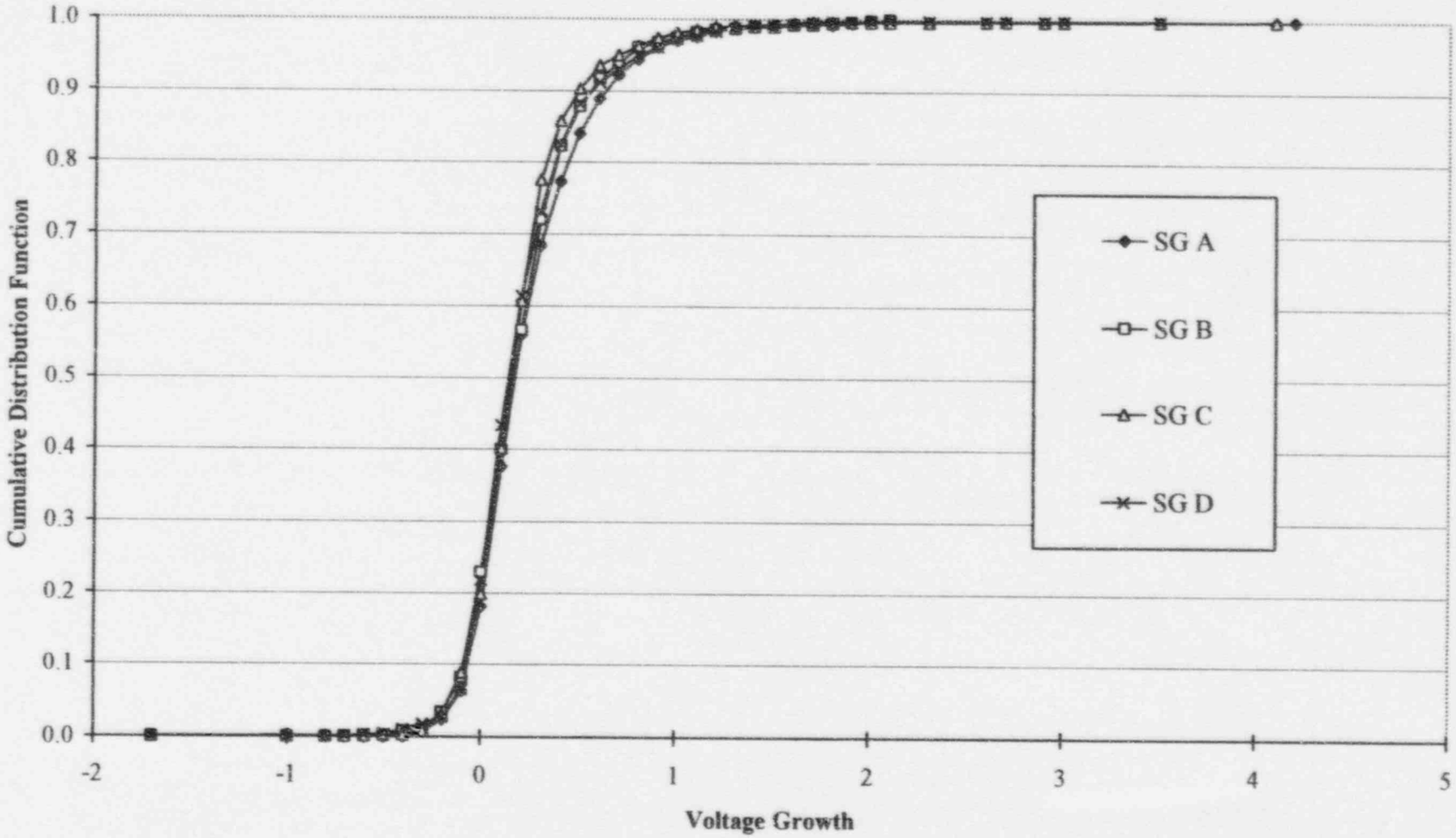
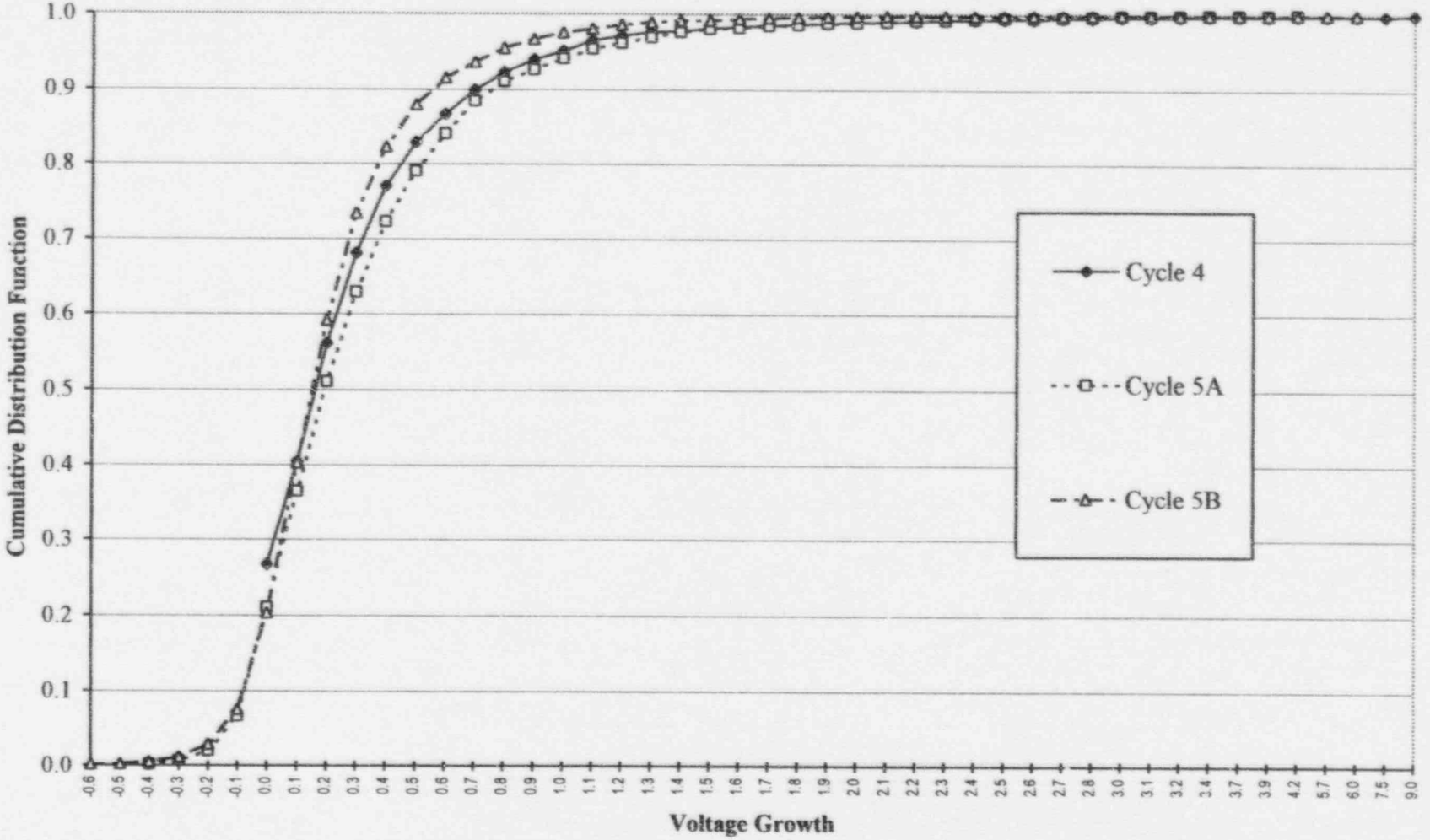


Figure 3 - 6
Braidwood Unit -1
Bobbin Signal Growth History - Cumulative Probability Distributions on an EFPY Basis
Composite of All Four Steam Generators



GROWTH.XLS\Figure 3-6

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. Braidwood-1 and Byron-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-5B and projected EOC-6 voltage distributions. The Monte Carlo analyses account for parameter uncertainty and they are consistent with the Braidwood Unit-1 SER. The analysis methodology is described in Braidwood-1 specific 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 November 1995 (Reference 8.7) and the second set for this 90 Day evaluation. To apply the recently NRC approved 3 volt IPC for Braidwood Unit-1 Cycle 6 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 5B 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-5B.

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-6 voltage distributions. Also, EOC-5B voltage distributions projected during the last (EOC-5A) inspection 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 corresponding cycle final distribution 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 indications measured to account for measurement 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 the 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:

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

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-6.

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 predictions during the last two inspections. Salient input data used for projecting EOC-6 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.

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 5A are higher than those of Cycle 5B, Cycle 5A growth rates are used to develop the EOC-6 predictions. The actual growth distribution used for EOC-6 projections is a worst case hybrid growth distribution which envelopes the highest average growth as well as the highest growth increment during Cycle 5A. This limiting growth distribution was developed during the last inspection for projecting EOC distributions for Cycle 5B. The same conservative growth distribution was imposed on all four steam generators to provide a conservative basis for predicting EOC-6 performance.

6.4 Cycle Operating Period

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

Cycle 5A	- BOC-5 to MOC-5	- 260.68 EFPD	or 0.714 EFPY (actual)
Cycle 5B	- MOC-5 to EOC-5	- 184.81 EFPD	or 0.506 EFPY (actual)
Cycle 6	- BOC-6 to EOC-6	- 493.1 EFPD	or 1.35 EFPY(estimated)

6.5 Projected EOC-6 Voltage Distribution

Calculation of the predicted EOC-6 bobbin voltage distributions was performed for all four SGs based on the EOC-5B 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 (TSPs constrain rupture of hot leg indications due to tube expansion). The beginning of cycle distributions were adjusted to account for probability of detection as described above, and the adjusted number of indications at the BOC-6 are also shown in Table 6-1. Calculations were performed using a constant POD of 0.6. A hybrid growth distribution based on Cycle 5A growth data, shown in Table 3-8, was used. The IPC voltage distributions projected for EOC-6 for all four

SGs are summarized on Table 6-2. These results are shown graphically on Figures 6-1 and 6-2. Since SG C has the largest number of indications, it is predicted to be the limiting SG for leak

6.6 Comparison of Actual and Projected EOC-5B Voltage Distributions

Table 6-3 and Figures 6-5 and 6-6 provide a comparison of the EOC-5B bobbin voltage distributions obtained during the recent inspection with the corresponding predictions performed during the last (EOC-5B) inspection using a constant POD of 0.6. As reported in Reference 8-5, SG C was projected to be the limiting SG. A comparison of the actual and projected voltage distributions indicate tha the indication population above 1 volt is substantially overestimated in the earlier projections. The primary cause for this overprediction is the use of a constant POD value of 0.6 for the entire voltage range. This POD value is conservative for voltages above about 1 volt but non-conservative below 1 volt. Also, 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, contributed to the observed conservatism for voltages above 1 volt.

Table 6 - 1 (Sheet 1 of 2)
Braidwood Unit-1 October 1995
Actual EOC-5B and Assumed BOC-6 Voltage Distributions
Used in SLB Leak Rate and Tube Burst Probability Analyses

Voltage Bin	Steam Generator A						Steam Generator B					
	EOC-5B				BOC-6		EOC-5B				BOC-6	
	In service		Repaired		POD = 0.6		In service		Repaired		POD = 0.6	
	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	0	0	0	0.00	0.00
0.2	3	0	0	0	5.00	0.00	2	0	0	0	3.33	0.00
0.3	47	3	0	0	78.33	5.00	10	0	0	0	16.67	0.00
0.4	102	3	1	0	169.00	5.00	62	3	0	0	103.33	5.00
0.5	138	1	3	0	227.00	1.67	59	1	0	0	98.33	1.67
0.6	143	1	3	0	235.33	1.67	95	0	0	0	158.33	0.00
0.7	117	0	5	0	190.00	0.00	67	1	0	0	111.67	1.67
0.8	114	1	1	0	189.00	1.67	63	0	1	0	104.00	0.00
0.9	104	0	2	0	171.33	0.00	52	0	0	0	86.67	0.00
1	65	1	2	0	106.33	1.67	53	0	0	0	88.33	0.00
1.1	66	1	1	0	109.00	1.67	25	0	0	0	41.67	0.00
1.2	45	0	0	0	75.00	0.00	28	0	0	0	46.67	0.00
1.3	24	0	0	0	40.00	0.00	12	0	0	0	20.00	0.00
1.4	16	0	0	0	26.67	0.00	7	0	0	0	11.67	0.00
1.5	8	0	0	0	13.33	0.00	5	0	0	0	8.33	0.00
1.6	8	0	1	0	12.33	0.00	2	0	1	0	2.33	0.00
1.7	4	0	0	0	6.67	0.00	3	0	0	0	5.00	0.00
1.8	7	0	1	0	10.67	0.00	2	0	0	0	3.33	0.00
1.9	1	0	0	0	1.67	0.00	0	0	0	0	0.00	0.00
2	3	0	0	0	5.00	0.00	3	0	0	0	5.00	0.00
2.1	2	0	0	0	3.33	0.00	1	0	0	0	1.67	0.00
2.2	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
2.3	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
2.4	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
2.5	1	0	0	0	1.67	0.00	0	0	0	0	0.00	0.00
2.6	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
2.7	1	0	0	0	1.67	0.00	0	0	0	0	0.00	0.00
2.8	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
2.9	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3.1	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3.2	1	0	1	0	0.67	0.00	0	0	0	0	0.00	0.00
3.3	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3.4	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
Total	1020	11	21	0	1679	18.33	551	5	2	0	916.33	8.33
> 1V	187	1	4	0	307.67	1.67	88	0	1	0	145.67	0.00
> 2V	5	0	1	0	7.33	0	1	0	0	0	1.67	0.00

Table 6 - 1 (Sheet 2 of 2)
Braidwood Unit-1 October 1995
Actual EOC-5B and Assumed BOC-6 Voltage Distributions
Used in SLB Leak Rate and Tube Burst Probability Analyses

Voltage Bin	Steam Generator C						Steam Generator D					
	EOC-5B				BOC-6		EOC-5B				BOC-6	
	In service		Repaired		POD = 0.6		In service		Repaired		POD = 0.6	
	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	1	0	0	0	1.67	0.00	0	0	0	0	0.00	0.00
0.2	7	0	0	0	11.67	0.00	5	0	0	0	8.33	0.00
0.3	25	0	1	0	40.67	0.00	21	0	0	0	35.00	0.00
0.4	122	0	1	0	202.33	0.00	88	1	0	0	146.67	1.67
0.5	167	1	1	0	277.33	1.67	141	0	1	0	234.00	0.00
0.6	164	0	3	0	270.33	0.00	145	0	3	0	238.67	0.00
0.7	199	0	3	0	328.67	0.00	144	0	1	0	239.00	0.00
0.8	200	0	3	0	330.33	0.00	136	0	2	0	224.67	0.00
0.9	164	0	2	0	271.33	0.00	111	0	1	0	184.00	0.00
1	129	0	2	0	213.00	0.00	88	0	1	0	145.67	0.00
1.1	107	0	0	0	178.33	0.00	63	0	0	0	105.00	0.00
1.2	71	0	1	0	117.33	0.00	36	0	0	0	60.00	0.00
1.3	36	0	0	0	60.00	0.00	36	0	2	0	58.00	0.00
1.4	28	0	1	0	45.67	0.00	19	0	0	0	31.67	0.00
1.5	25	0	0	0	41.67	0.00	13	0	0	0	21.67	0.00
1.6	8	0	0	0	13.33	0.00	5	0	0	0	8.33	0.00
1.7	7	0	0	0	11.67	0.00	7	0	0	0	11.67	0.00
1.8	5	0	0	0	8.33	0.00	4	0	0	0	6.67	0.00
1.9	4	0	0	0	6.67	0.00	2	0	0	0	3.33	0.00
2	1	0	0	0	1.67	0.00	1	0	0	0	1.67	0.00
2.1	3	0	0	0	5.00	0.00	0	0	0	0	0.00	0.00
2.2	1	0	0	0	1.67	0.00	1	0	0	0	1.67	0.00
2.3	3	0	1	0	4.00	0.00	0	0	0	0	0.00	0.00
2.4	0	0	0	0	0.00	0.00	1	0	0	0	1.67	0.00
2.5	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
2.6	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
2.7	0	0	0	0	0.00	0.00	1	0	0	0	1.67	0.00
2.8	1	0	0	0	1.67	0.00	0	0	0	0	0.00	0.00
2.9	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3	1	0	0	0	1.67	0.00	0	0	0	0	0.00	0.00
3.1	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3.2	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3.3	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
3.4	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00
Total	1479	1	19	0	2446.00	1.67	1068	1	11	0	1769.00	1.67
> 1V	301	0	3	0	498.67	0.00	189	0	2	0	313.00	0.00
> 2V	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00

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Table 6 - 2 (Sheet 1 of 2)
Braidwood Unit-1 October 1995
Voltage Distribution Projection for EOC - 6

Voltage Bin	Steam Generator A	Steam Generator B	Steam Generator C	Steam Generator D
	Projected Number of Indications at EOC -6 , POD = 0.6			
0.1	0.05	0.03	0.52	0.08
0.2	2.88	1.09	3.61	2.58
0.3	23.01	7.29	16.37	12.87
0.4	53.01	26.76	55.95	42.84
0.5	83.43	41.62	93.76	76.29
0.6	105.44	58.25	126.45	103.00
0.7	118.82	66.52	158.19	123.22
0.8	127.46	70.95	180.29	135.60
0.9	129.68	72.64	190.45	140.29
1.0	126.31	71.25	190.81	136.84
1.1	119.05	66.84	181.52	128.45
1.2	109.10	60.92	167.07	117.09
1.3	97.99	54.33	150.63	105.22
1.4	86.10	47.67	133.48	93.54
1.5	74.21	40.94	116.21	80.99
1.6	63.33	34.71	99.20	69.13
1.7	54.01	29.27	84.89	58.73
1.8	46.30	24.86	72.20	50.03
1.9	39.64	21.35	61.31	42.60
2.0	33.78	18.96	52.00	36.13
2.1	28.93	15.53	44.24	30.70
2.2	24.70	13.26	37.91	26.27
2.3	20.90	11.32	32.40	22.43
2.4	17.64	9.58	27.47	18.97
2.5	14.98	8.05	23.40	16.04
2.6	12.73	7.13	19.87	13.59
2.7	11.53	5.77	16.84	11.48
2.8	9.18	4.85	14.19	9.73
2.9	7.78	4.12	12.08	8.22
3.0	6.59	3.45	10.19	6.92
3.1	5.69	2.96	8.76	5.94
3.2	4.92	2.56	7.61	5.18
3.3	4.21	2.20	6.50	4.43
3.4	3.86	1.86	5.51	3.75
3.5	3.05	1.57	4.76	3.19
3.6	2.69	1.38	4.18	2.80
3.7	2.38	1.22	3.62	2.45
3.8	2.04	1.06	3.12	2.11
3.9	1.76	0.91	2.70	1.83
4.0	1.52	0.78	2.34	1.59
4.1	1.33	0.68	2.05	1.40
4.2	1.20	0.61	1.81	1.25
4.3	1.09	0.57	1.64	1.12
4.4	1.01	0.52	1.50	1.03
4.5	0.92	0.49	1.37	0.97

Continued on next page

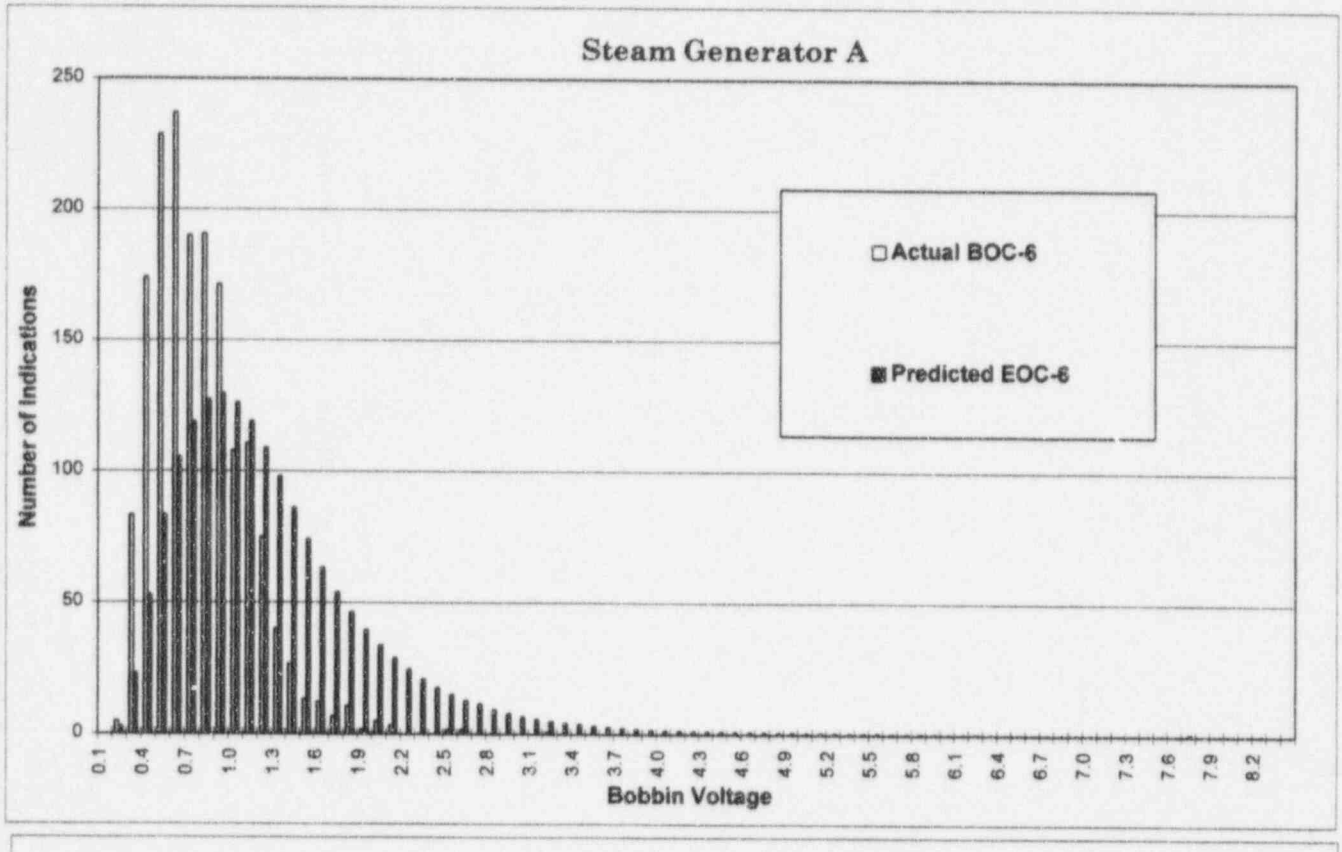
Table 6 - 2 (Sheet 2 of 2)
Braidwood Unit-1 October 1995
Voltage Distribution Projection for EOC - 6

Voltage Bin	Steam Generator A	Steam Generator B	Steam Generator C	Steam Generator D
	Projected Number of Indications at EOC -6 , POD = 0.6			
4.6	0.85	0.45	1.26	0.88
4.7	0.79	0.41	1.19	0.85
4.8	0.76	0.40	1.13	0.79
4.9	0.73	0.39	1.08	0.77
5.0	0.68	0.36	1.02	0.72
5.1	0.63	0.34	0.94	0.66
5.2	0.59	0.32	0.88	0.62
5.3	0.55	0.29	0.83	0.58
5.4	0.50	0.27	0.77	0.53
5.5	0.46	0.25	0.68	0.49
5.6	0.42	0.23	0.62	0.44
5.7	0.37	0.21	0.58	0.41
5.8	0.34	0.18	0.52	0.36
5.9	0.32	0.17	0.47	0.33
6.0	0.29	0.16	0.44	0.31
6.1	0.26	0.15	0.40	0.28
6.2	0.23	0.13	0.35	0.25
6.3	0.21	0.11	0.32	0.22
6.4	0.18	0.09	0.28	0.19
6.5	0.15	0.04	0.24	0.16
6.6	0.14	0	0.21	0.14
6.7	0.12	0	0.18	0.13
6.8	0.11	0	0.16	0.12
6.9	0.10	0	0.15	0.11
7.0	0.09	0	0.14	0.10
7.1	0.10	0.70	0.13	0.10
7.2	0.09	0	0.13	0.09
7.3	0.03	0	0.12	0.09
7.4	0	0	0.13	0.02
7.5	0	0	0.13	0
7.6	0	0	0.12	0
7.7	0.70	0	0.07	0
7.8	0	0	0	0.70
7.9	0	0.30	0	0
8.0	0		0.70	0
8.1	0		0	0
8.2	0.30		0	0
8.3			0	0.30
8.4			0.30	
TOTAL	1697.32	924.63	2447.64	1770.65
> 1 V	927.23	508.23	1431.24	997.04
> 3 V	48.76	25.32	74.14	50.78

Table 6 - 3
Braidwood Unit-1 October 1995
Comparison of Predicted and Actual EOC-5B Voltage Distributions

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C		Steam Generator D	
	EOC-5B Prediction	EOC-5B Actual	EOC-5B Prediction	EOC-5B Actual	EOC-5B Prediction	EOC-5B Actual	EOC-5B Prediction	EOC-5B 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	POD=.6 No. of Indications	No. of Indications
0.1	0.01	0	0.00	0	0.01	1	0.01	0
0.2	1.60	3	0.45	2	1.00	7	0.80	5
0.3	15.51	50	6.18	10	11.05	25	7.93	21
0.4	47.44	105	23.25	65	44.09	122	31.60	89
0.5	89.70	139	44.38	60	99.06	168	66.00	141
0.6	125.82	144	61.99	95	153.52	164	101.19	145
0.7	150.71	117	70.32	68	193.85	199	128.96	144
0.8	161.67	115	70.48	63	222.59	200	144.01	136
0.9	158.20	104	67.70	52	237.41	164	145.53	111
1.0	140.25	66	62.47	53	229.15	129	138.07	88
1.1	114.17	67	53.18	25	197.00	107	121.13	63
1.2	89.22	45	41.79	28	155.91	71	96.54	36
1.3	68.73	24	31.71	12	119.68	36	72.39	36
1.4	52.44	16	23.67	7	91.21	28	53.37	19
1.5	39.88	8	17.45	5	69.28	25	39.46	13
1.6	30.43	8	12.82	2	52.64	8	29.33	5
1.7	23.38	4	9.55	3	39.67	7	21.66	7
1.8	18.05	7	7.25	2	29.95	5	15.88	4
1.9	14.17	1	0.00	0	22.95	4	11.87	2
2.0	11.36	3	4.24	3	17.75	1	9.25	1
2.1	9.20	2	3.25	1	13.57	3	7.34	0
2.2	7.38	0	2.45	0	10.29	1	5.67	1
2.3	5.87	0	1.80	0	7.78	3	4.26	0
2.4	4.64	0	1.27	0	5.95	0	3.16	1
2.5	3.69	1	0.90	0	4.65	0	2.38	0
2.6	2.96	0	0.64	0	3.73	0	1.85	0
2.7	2.39	1	0.46	0	3.10	0	1.49	1
2.8	0.00	0	0.34	0	2.63	1	1.22	0
2.9	1.60	0	0.79	0	0.00	0	1.02	0
3.0	1.32	0	0.00	0	1.84	1	0.89	0
3.1	1.11	0	0.00	0	1.50	0	0.76	0
3.2	0.96	1	0.00	0	1.20	0	0.00	0
3.3	0.87	0	0.00	0	0.95	0	0.59	0
3.4	0.80	0	0.00	0	0.77	0	0.52	0
3.5	0.72	0	0.70	0	0.62	0	0.86	0
3.6	0.60	0	0.00	0	0.50	0	0.00	0
3.7	0.49	0	0.30	0	0.40	0	0.00	0
3.8	0.71	0		0	0.83	0	0.00	0
3.9	0.00	0		0	0.00	0	0.70	0
4.0	0.00	0		0	0.00	0	0.00	0
4.1	0.00	0		0	0.00	0	0.30	0
4.3	0.70	0		0	0.00	0		0
4.5	0.30	0		0	0.00	0		0
5.3		0		0	0.70	0		0
5.6		0		0	0.30	0		0
TOTAL	1399.05	1031	621.78	556	2049.08	1480	1267.99	1069
> 1.0 V	508.14	188	214.56	88	857.35	301	503.89	189
> 3 V	7.26	1	1.00	0	7.77	0	3.73	0

Figure 6-1
Braidwood Unit-1 October 1995
Predicted Bobbin Voltage Distribution for Cycle 6, POD = 0.6



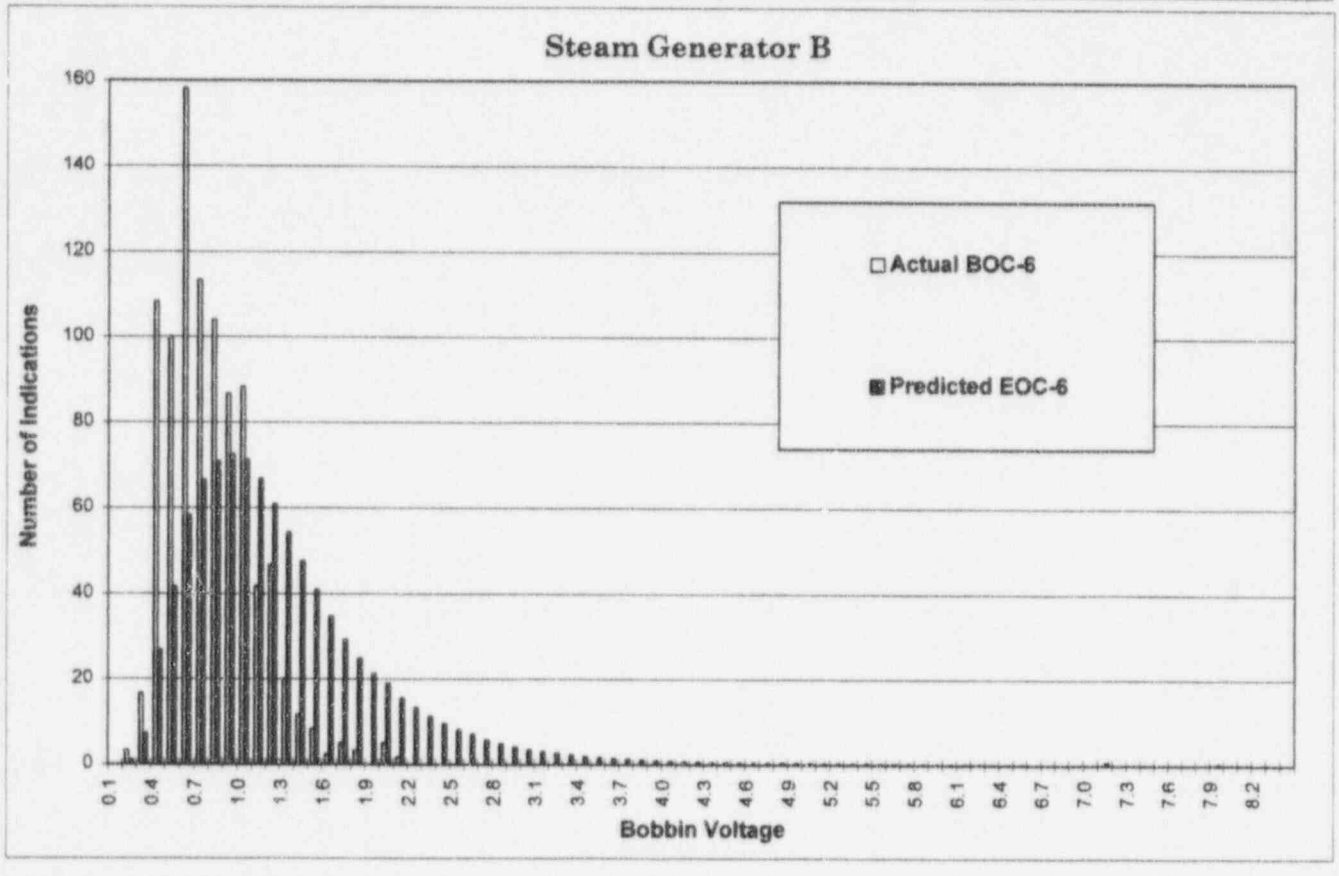
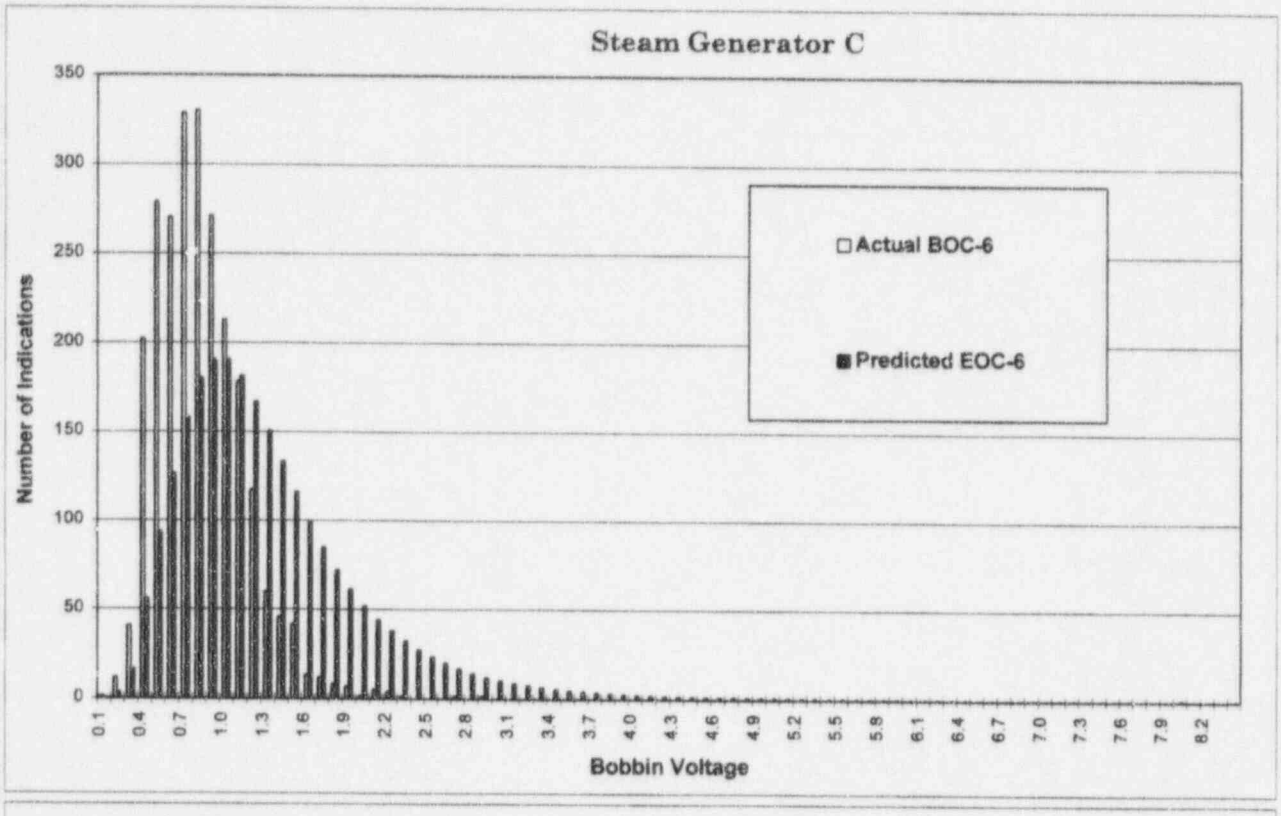


Figure 6-2
Braidwood Unit-1 October 1995
Predicted Bobbin Voltage Distribution for Cycle 6, POD = 0.6



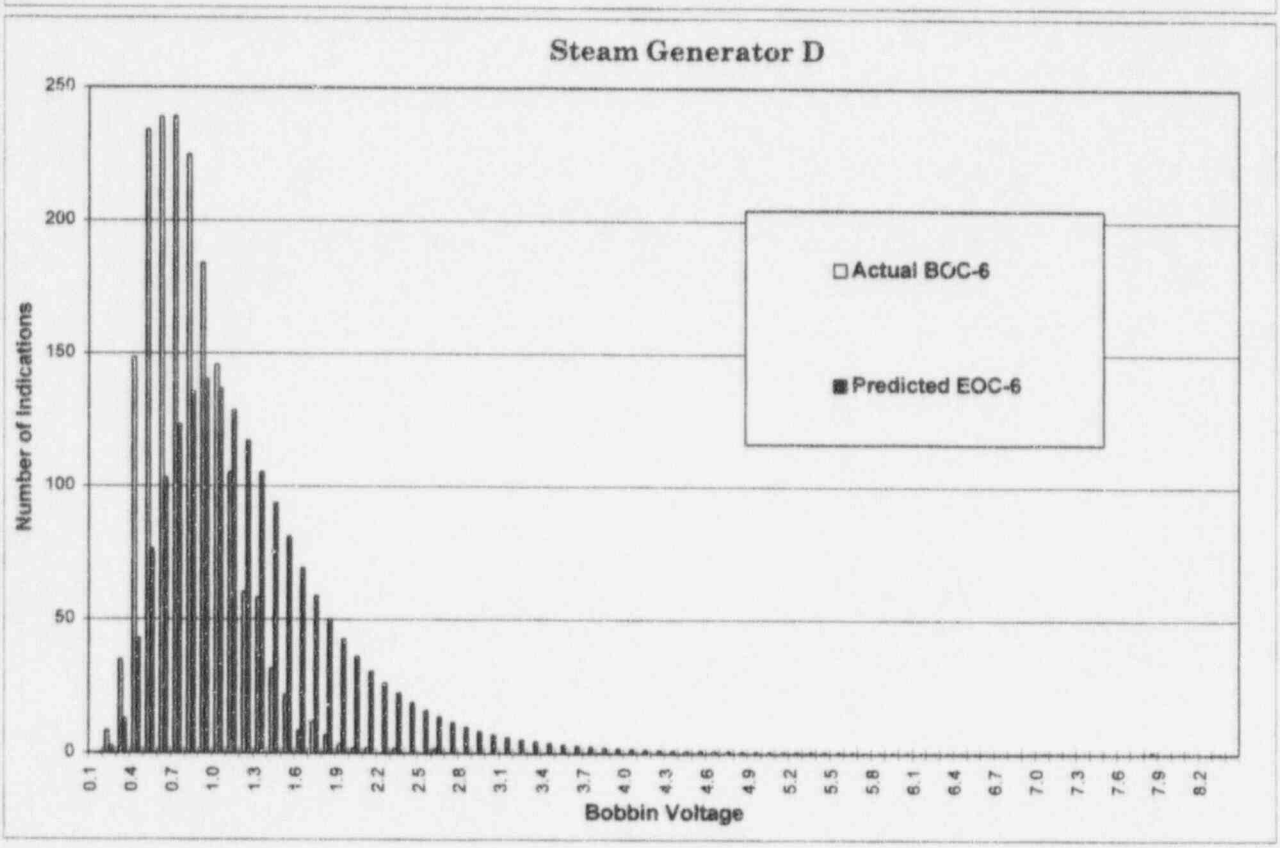
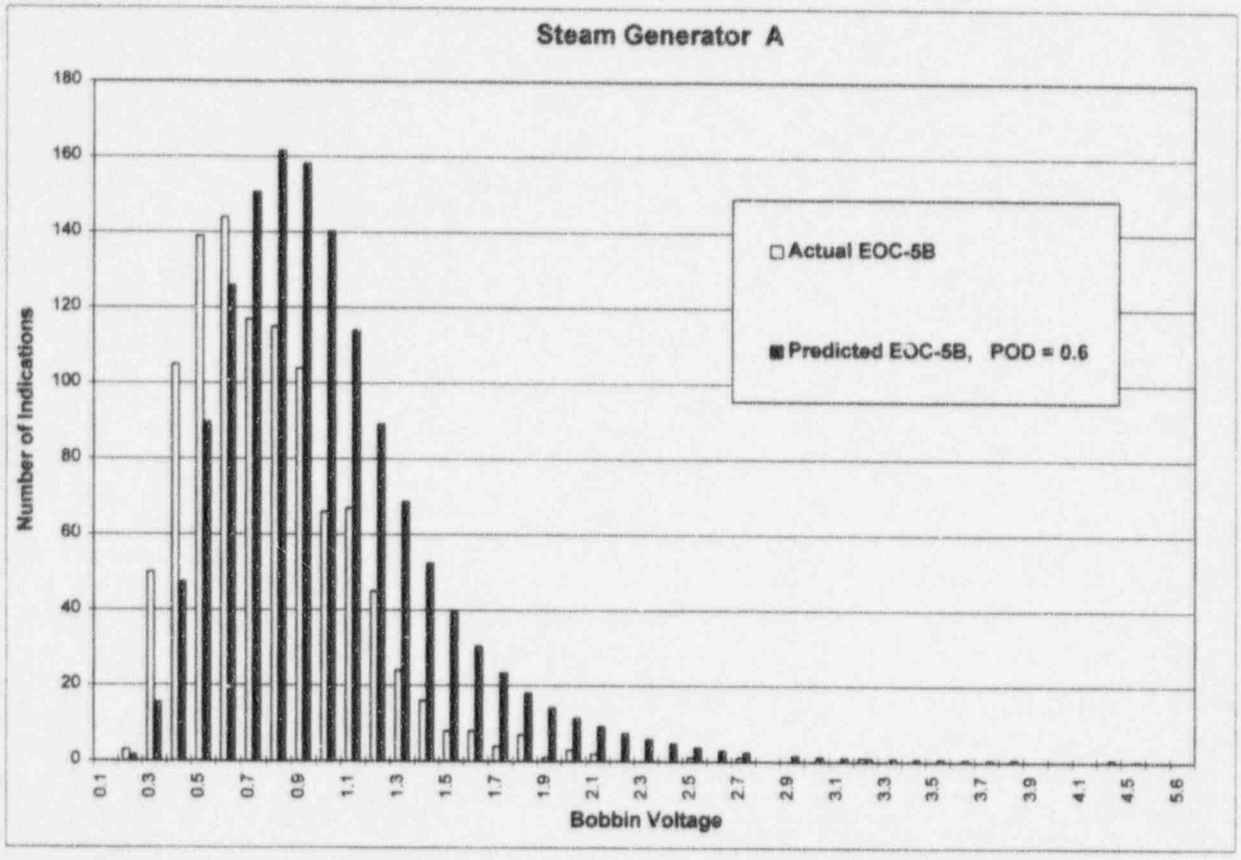


Figure 6 - 3
Braidwood Unit-1 October 1995
Bobbin Voltage Distributions for Cycle 5-B



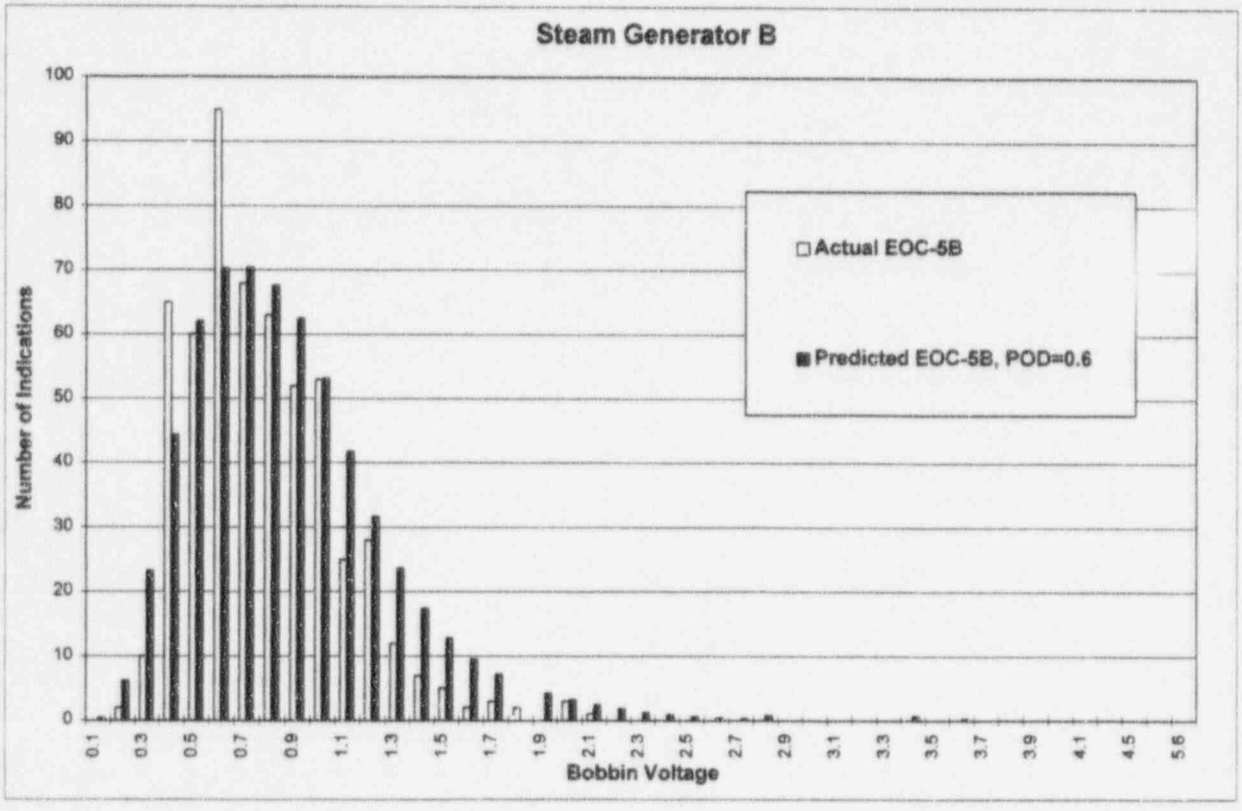
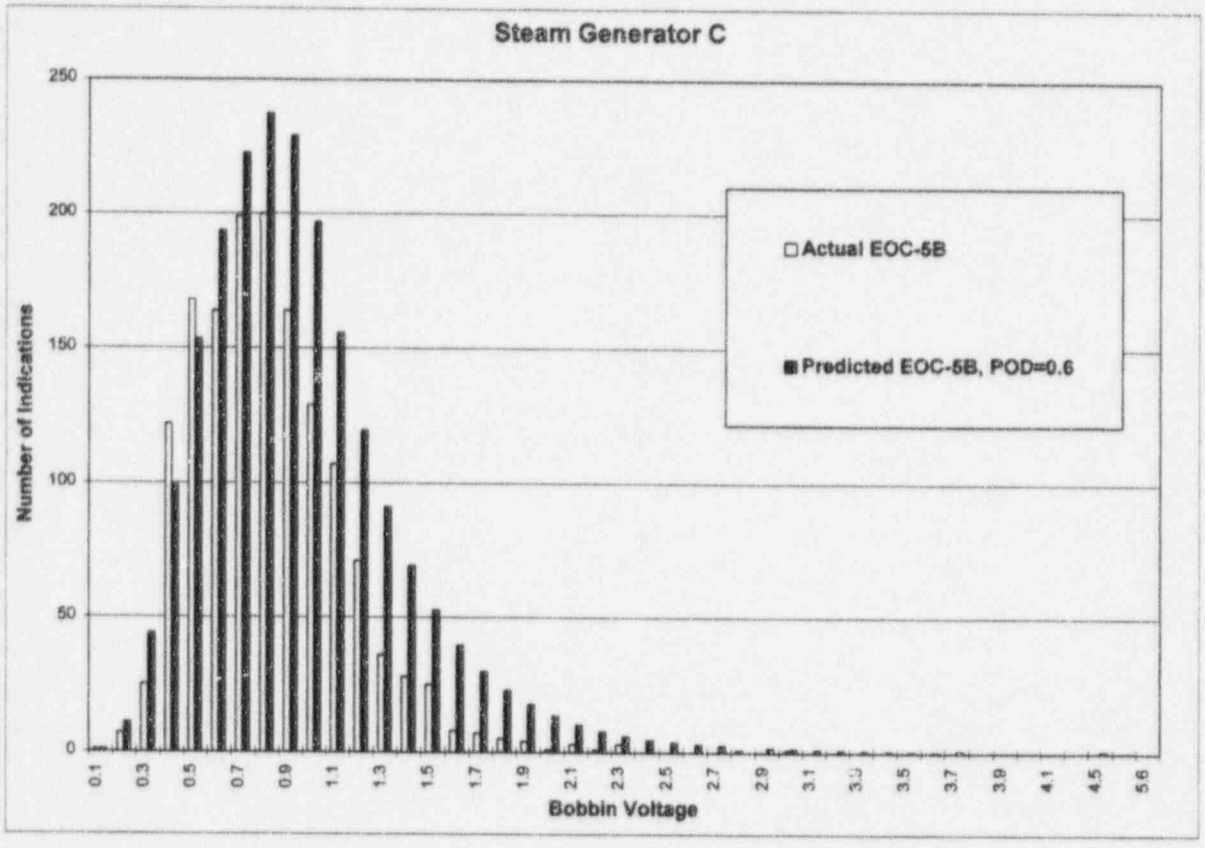
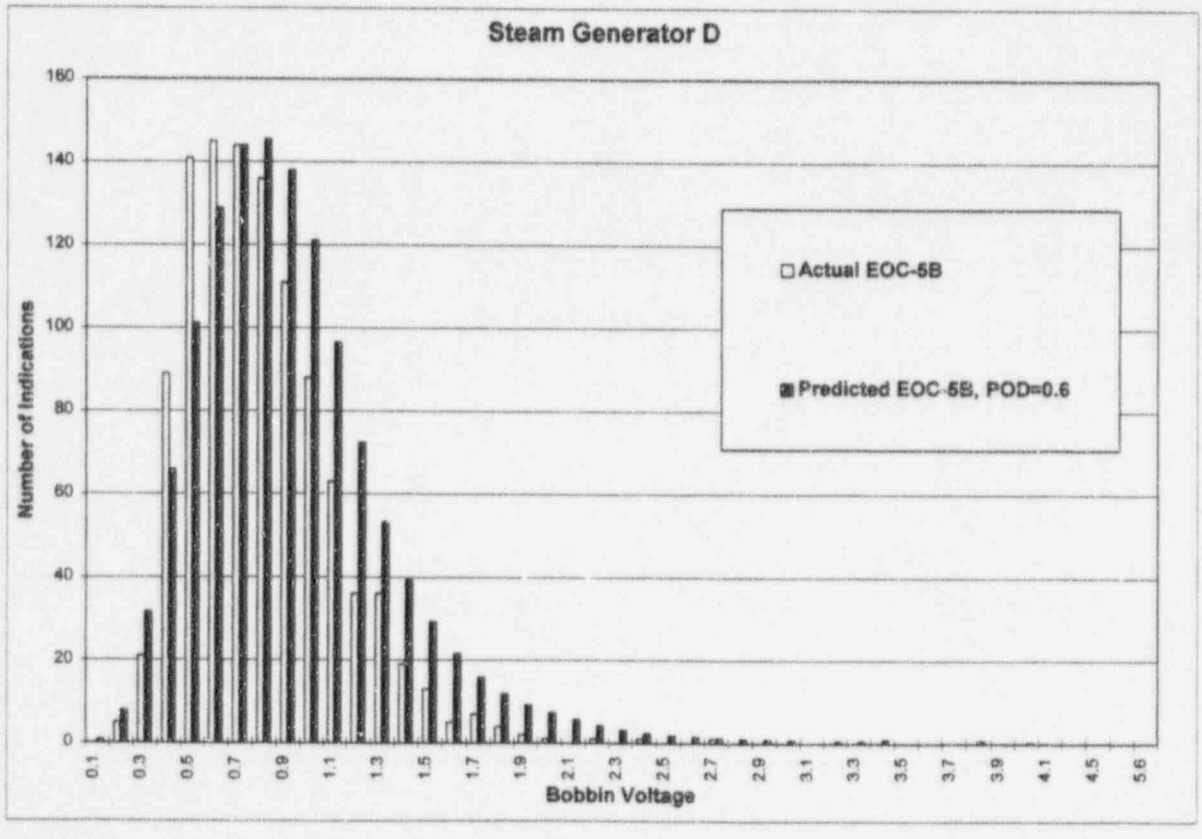


Figure 6 - 4
Braidwood Unit-1 October 1995
Bobbin Voltage Distributions for Cycle 5-B





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-5B inspection as well as for the projected EOC-6 voltage distributions. The methodology used in these analyses is described in Section 5.0. For the TSP locked condition during Cycle 6 (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. SG C is expected to yield the limiting SLB leak rate for Cycle 6 since it had the largest number of indications on the hot leg side, see Table 6-1, while 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-5B

Analyses to calculate EOC-5B 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). The results of Monte Carlo calculations are summarized on Table 7-1. The free span analyses (without TSP locking) are the reference analyses for Cycle 5B and their results are to be compared with allowable limits. Comparison of the EOC-5B actuals with the corresponding predictions indicates that:

a) SG C was predicted to be the most limiting steam generator for EOC-5B with the highest leak rate and tube burst probability.

b) SG C was also determined to have the highest leak rate and tube burst probabilities based on actual EC bobbin measurements for EOC-5B.

c) The leak rate and tube burst probability predictions (based on projected indication population) for all four SGs are conservative compared to the corresponding values based on EC bobbin measurements for EOC-5B even for the free span conditions. Overall, the projections for all SG's are conservative by at least a factor of 4.8.

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

In summary, the limiting free span SLB leak rate (0.07 gpm) and burst probability (6.49×10^{-4}) calculated using the actual EOC-5B bobbin voltage distributions are below the corresponding projections assuming a voltage frequency based on the NRC SER endorsed probability of detection (POD) of 0.6. Also, these values are much lower

than the allowable SLB leakage limit of 9.1 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 tube burst probability by over two orders of magnitude.

7.2 Leak Rate and Tube Burst Probability for EOC-6

Calculations to predict the performance of the limiting steam generator in Braidwood Unit-1 at EOC-6 conditions were carried using NRC required constant POD value of 0.6. The methodology used in these predictions is the same as previously described for EOC-5B. Results of the EOC-6 predictions are summarized in Table 7-2. With a constant POD of 0.6, the projected limiting EOC-6 SLB leak rate is 6.99 gpm (SG C), and the limiting tube burst probability is 6.81×10^{-4} (SG A). Both these limiting values are projected for SG C. These values are much lower than the allowable SLB leakage limit for Cycle 6 of 26.8 gpm and the NRC reporting guideline of 10^{-2} for the tube burst probability.

Table 7-1

Braidwood Unit-1 October 1995 Outage
Summary of Calculations of Tube Leak Rate and Burst Probability
Based on EOC-5B Actual Bobbin Voltage - 250k Simulations

Steam Generator		POD	No. of Indications[1]	Max. Volts[2]	Burst Probability		SLB Leak Rate gpm
					1 Tube	2 Tubes	
EOC - 5B PROJECTIONS from EOC - 5A							
A		0.6	1401	4.5	2.92×10^{-3}	4.75×10^{-5}	0.33
B		0.6	627	3.7	7.81×10^{-4}	$< 4.0\times10^{-6}$	0.08
C		0.6	2051	5.6	4.94×10^{-3}	4.20×10^{-5}	0.48
D		0.6	1269.	4.1	1.97×10^{-3}	4.20×10^{-5}	0.22
EOC - 5B ACTUAL (Free Span - Without Tube Support Plates Locked)							
A		1	1031	3.5	2.98×10^{-4}	$< 4.0\times10^{-6}$	0.06
B		1	556	2.5	9.72×10^{-5}	$< 4.0\times10^{-6}$	0.01
C		1	1480	3.4	6.49×10^{-4}	$< 4.0\times10^{-6}$	0.07
D		1	1069	3.0	4.12×10^{-4}	$< 4.0\times10^{-6}$	0.04
EOC - 5B ACTUAL (Tube Support Plates Assumed Locked)							
A	Hot Side	1	1020	3.5	Negligible[3]	Negligible[3]	0.06
	Cold	1	11	1.3	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1.0×10^{-4}
	Total	-	1031	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.06
B	Hot Side	1	551	2.5	Negligible[3]	Negligible[3]	0.02
	Cold	1	5	0.9	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1.0×10^{-4}
	Total	-	556	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.02
C	Hot Side	1	1479	3.4	Negligible[3]	Negligible[3]	0.07
	Cold	1	1	0.7	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1.0×10^{-4}
	Total	-	1480	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.07
D	Hot Side	1	1068	3.0	Negligible[3]	Negligible[3]	0.04
	Cold	1	1	0.6	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	1.0×10^{-4}
	Total	-	1069	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.04

(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).

Table 7-2
Braidwood Unit-1 October 1995 Outage
Summary of Projected Tube Leak Rate and Burst Probability
for EOC-6 - 250k Simulations

Steam Generator		POD	No. of Indications[1]	Max. Volts[2]	Burst Probability		SLB Leak Rate gpm
					1 Tube	2 Tubes	
EOC - 6 PROJECTIONS							
A	Hot Side	0.6	1679	8.2	Negligible[3]	Negligible[3]	5.61
	Cold	0.6	18	3.4	6.81×10^{-4}	$< 4.0\times10^{-6}$	0.02
	Total	0.6	1697	-	6.81×10^{-4}	$< 4.0\times10^{-6}$	5.63
B	Hot Side	0.6	916	7.9	Negligible[3]	Negligible[3]	2.35
	Cold	0.6	8	2.6	2.04×10^{-4}	$< 4.0\times10^{-6}$	0.005
	Total	0.6	924	-	2.04×10^{-4}	$< 4.0\times10^{-6}$	2.36
C	Hot Side	0.6	2446	8.4	Negligible[3]	Negligible[3]	6.99
	Cold	0.6	2	1.5	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	0.0
	Total	0.6	2448	-	$< 4.0\times10^{-6}$	$< 4.0\times10^{-6}$	6.99
D	Hot Side	0.6	1769	8.3	Negligible[3]	Negligible[3]	6.2
	Cold	0.6	18	3.4	1.07×10^{-4}	$< 4.0\times10^{-6}$	0.0
	Total	0.6	1787	-	1.07×10^{-4}	$< 4.0\times10^{-6}$	6.2

(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, June 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.

8.6 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.

8.7 Westinghouse Report NSD-SGD-1176, "Braidwood Unit-1, Interim Plugging Criteria Return to Power Report," Westinghouse Nuclear Service Division, November 1995.