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BRAIDWOOD UNIT 1

1995 INTERIM PLUGGING CRITERIA 90 DAY REPORT

JUNE 1995

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1.0 INTRODUCTION

This report provides the Braidwood Unit 1 steam generator tube Eddy Current Test (ECT) inspection results together with Steam Line Break (SLB) leak rate and tube burst probability analysis results, in support of the implementation of a 1.0 volt Interim Plugging Criteria (IPC) at Middle Of Cycle 5 (MOC-5) according to NRC guidelines. Comparisons of the actual MOC-5 voltage distributions as well as leak rates and tube burst probabilities (POB) calculated with these distributions (based on MOC-5 ECT data) are made with the corresponding projections for MOC-5 (based on the previous cycle 4 data). Also provided are projections of ECT tube voltage distributions, leak rates and burst probabilities for the completion of Cycle 5 operation (MOC-5 to EOC-5)[*]. The methodology used in these evaluations is in accordance with previously published Westinghouse reports (References 8.1, 8.2).

The application of the Interim Plugging Criteria (IPC) at Braidwood Unit 1 involves 100% Eddy Current Test (ECT) of the tube bundle and plugging of >1.0 volt indications which are confirmed by Rotating Pancake Coil (RPC). Plugging of >2.7 volt bobbin indications is performed regardless of any RPC inspection. Along with this field activity, an analysis is performed to predict the tube leakage rate and burst probability for a postulated SLB accident during the remainder of Cycle 5. Since tube degradation increases with time during operation, it is most likely that the maximum estimate for tube leak rate and burst probability would occur at the end of a cycle; the analysis does not take into account unexpected events that could alter this probability.

2.0 SUMMARY AND CONCLUSIONS

SLB leak rate and tube burst probability analyses were performed for the actual EOC-5A ECT bobbin voltage distributions and are conservative (lower) relative to corresponding projections for EOC-5A calculated with a Probability of Detection (POD) of 0.6 by approximately an order of magnitude. SG C was found to be the limiting SG at actual EOC-5A voltage distributions.

[*] For clarity, BOC-5 to MOC-5 will be referred to as cycle 5A (from BOC- 5A to EOC-5A) and MOC-5 to EOC-5 as cycle 5B (from BOC-5B to EOC-5B).

For the actual EOC-5A bobbin voltage distribution, the SLB leak rate is calculated to be 0.32 gpm and the burst probability is 3.04 E-03 for SG C; these values are below the corresponding projections for SG C 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 prediction expected SG D to be more limiting than SG C at EOC-5A because of significantly higher voltage indications at EOC-4, although SG C had a larger number of low voltage indications. The projections for SG D yield SLB leakage and tube burst probability that are close to a factor of 10 higher than obtained for the actual limiting SG C. This supports the conservatism of the IPC methodology of applying the limiting SG as the basis for IPC analyses.

Comparisons of the EOC-5A projections with the actual distribution for SG C show that a POD of 0.6 overestimates the actual distribution above 0.9 volts although slightly underestimating the maximum voltage (4.9 volts versus actual 5.2 volts). The projections for SG D are excessively conservative in predicting the higher voltage (above 1.6 volts for SG D and about 2.8 volts for SG C) tail of the distribution due to applying the POD = 0.6 to EOC-4 indications above about 2 to 3 volts. These results show the value of applying a voltage dependent POD.

A total of 3935 indications were found in the EOC-5A inspection of which 1125 were RPC inspected (including all indications above 1.0 volt) and 874 were confirmed as flaws by the RPC inspection. The RPC confirmed indications included 836 above 1.0 volt. SG C had 1526 bobbin indications, of which 431 were above 1.0 volt and 339 of these were confirmed by RPC inspection. 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 MOC-5 INSPECTION RESULTS AND VOLTAGE GROWTH RATES

3.1 MOC-5 INSPECTION RESULTS

In accordance with the IPC guidance provided by the NRC draft generic letter, the Middle Of Cycle 5 inspection of the Braidwood Unit 1 steam generators (SG) consisted of a complete, 100% Eddy Current Test (ECT) bobbin probe full length examination of all TSP intersections in the tube bundles of the four SGs. A 0.610 inch diameter probe was used for all hot and cold leg TSPs where IPC was applied. Subsequently, Rotating Pancake Coil (RPC) examination was performed for all bobbin indications with amplitudes > 1.0 volt. RPC confirmed indications > 1.0 bobbin volt were plugged. In addition, an augmented RPC inspection was performed consistent with the NRC requirements.

The augmented RPC inspection included dented TSP intersections with dent voltages > 2.5 volts, 40 artifact signals and 20 indications with bobbin voltages < 1.0 volt. There were no RPC flaw indications reported in the augmented inspection.

There was no evidence of any unexpected eddy current results at MOC-5. 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 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 ECT indication statistics 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. The indications that remain active for the cycle 5B 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 3935 indications identified during the inspection, a total of 2725 indications were returned to service for cycle 5B.
- Of the 3935 indications, a total of 1125 were RPC inspected.
- Of the 1125 RPC inspected, a total of 874 were RPC confirmed.
- A total of 1210 indications were removed from service. The RPC confirmed but not removed from service indications have bobbin amplitudes of ≤ 1.0 volt.

Review of Table 3-1 indicates that steam generator C has more and higher BOC-5B indications (a quantity of 1034, with 79 indications >1.0 volt) than SG A, B or D, thereby it potentially will be the limiting SG at EOC-5B. Figure 3-1 shows the actual bobbin voltage distribution determined from the EOC-5A ECT inspection; Figure 3-2 shows the population distribution of those EOC-5A indications which were plugged and taken out of service; Figure 3-3 shows the indications which are being returned to service for cycle 5B.

The distribution of EOC-5A indications as a function of support plate elevation, summarized in Table 3-2 and shown on Figure 3-4, shows the predisposition of ODSCC to occur in the first few hot leg TSPs (3827 of 3935 indications occurred in the first four TSPs), although the mechanism did extend to higher TSPs, including a few in the cold leg. This distribution indicates the predominant temperature dependence of ODSCC at Braidwood Unit 1, similar to that observed at other plants.

Of the 3935 total indications represented by Table 3-2, nine IPC indications were reported in coldleg TSPs. All nine indications were < 1.0 volt. Two of the affected tubes were plugged, because of hot leg IPC indications in those two tubes.

3.2 VOLTAGE GROWTH RATES

For projection of cycle 5B operation, voltage growth rates are developed from the March 1995 inspection data and a reevaluation of the same indications from the previous (1994) inspection ECT signals. The previous cycle 4 growth rate and indication distributions at BOC-5A are used to develop the EOC-5A predictions, but cycle 5A growth rates, found to be slightly more conservative than cycle 4 values, are used to develop the EOC-5B predictions. Of the 3935 bobbin indications found in the 1995 inspection, the growth for cycle 5A could be calculated for 3884 indications since a reliable value for 1994 bobbin voltage could not be obtained for the others.

Growth statistics for the Braidwood Unit 1 steam generators, shown on Table 3-3, provide a comparison of the last three operating periods (1991 - 1992, 1992 - 1994 and 1994 - 1995). Table 3-3 indicates that the growth rate per EFPY decreased from cycle 3 to cycle 4 and increased from cycle 4 to cycle 5A.

Table 3-3 compares the average voltage growth rates for Cycles 3, 4 and 5A, with cycle 5A growth exceeding that of cycle 4. The trend of the growth data summarized on Table 3-3 is not conclusive. Cycle 4 indicates a reduced growth rate (from 89% to 47% per EFPY), compared to Cycle 3, with the implication that chemistry enhancements have been effective in reducing the growth of ODSCC indications at the TSP intersections. During the protracted 1994-1995 operating period of cycle 5A, the average growth changed from 47% to 72%, on a comparable EFPY basis.

Average growth rates in each SG for cycle 5A (1994 - 1995) are shown in Table 3-4 The average growth rates vary between 49% and 86% per EFPY, between SGs, with an overall average of 72% per EFPY. The average growth for indications ≥ 0.75 volt is 64% per EFPY and for indications < 0.75 volt is 75% per EFPY. SG C has the the highest average voltage at BOC-5A whereas SG A has the largest average voltage growth during cycle 5A. Table 3-5 shows the cumulative probability distribution function of each SG during cycles 4 and 5A, on an EFPY basis for relative comparison; these growth rates were used for the midcycle predictions in the return-to-power evaluation. The guidance of the NRC draft generic letter recommends that the more conservative growth distribution from the last two cycles be used for projecting EOC distributions. For conservatism consistent with the NRC guidance, a worst case hybrid growth distribution is defined on Table 3-5, which 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).

This hybrid growth was imposed on all four steam generators, to provide a conservative basis for predicting EOC-5B performance. Table 3-6 shows distribution functions that were used for the 90 Day evaluation. Table 3-7 lists the largest growth rates, in descending order, that were developed during cycle 5A; it is noted that all of these bobbin calls were RPC confirmed.

3.3 NDE UNCERTAINTIES

The NDE uncertainties applied for the cycle 5 voltage projections in this report are the same as those previously reported in the Braidwood Unit 1 IPC report of Reference 8.1. 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-5 voltage distributions.

Table 3-1
Braidwood Unit 1 - Steam Generator IPC
Summary of Inspection and Plugging During EOC-5A

Delta Volts Bin	Steam Generator A				Steam Generator B				Steam Generator C				Steam Generator D				Combined Data			
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Plugged	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Plugged	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Plugged	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Plugged	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Plugged
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	4	0	0	0	1	0	0	0	3	0	0	1	2	0	0	0	10	0	0	1
0.3	40	1	0	1	16	1	0	0	31	0	0	6	21	1	0	3	108	3	0	10
0.4	66	4	0	11	46	2	0	1	93	3	1	10	87	2	1	5	292	11	2	27
0.5	118	4	1	11	52	4	1	4	152	2	1	19	88	3	2	9	410	13	5	43
0.6	118	4	2	14	61	4	2	2	168	1	0	29	115	2	1	15	462	11	5	60
0.7	136	1	0	23	46	1	1	5	173	3	1	25	115	1	1	14	470	6	3	67
0.8	113	1	1	23	43	8	[illegible]	3	182	1	1	19	107	2	1	12	445	12	11	57
0.9	103	5	3	19	37	4	0	0	166	2	0	16	86	0	0	12	392	11	3	47
1.0	51	2	1	9	33	3	3	1	127	2	1	15	89	5	4	14	300	12	9	39
1.1	70	70	54	55	19	19	9	9	100	100	75	79	66	66	44	44	255	255	182	187
1.2	54	54	49	50	17	17	8	8	91	91	63	67	46	46	37	39	208	208	157	164
1.3	38	38	31	32	11	11	5	5	56	56	47	47	34	34	28	28	139	139	111	112
1.4	25	25	22	23	9	9	8	8	45	45	38	40	19	19	15	16	98	98	83	87
1.5	24	24	20	22	5	5	2	2	39	39	31	32	18	18	15	15	86	86	68	71
1.6	18	18	18	18	2	2	1	1	25	25	21	21	18	18	17	17	63	63	57	57
1.7	12	12	9	10	6	6	4	4	13	13	12	13	5	5	5	5	36	36	30	32
1.8	10	10	10	10	2	2	2	2	18	18	14	14	5	5	5	5	35	35	31	31
1.9	7	7	7	7	2	2	2	2	10	10	7	8	9	9	9	9	28	28	25	26
2.0	10	10	8	8	3	3	2	2	6	6	4	4	8	8	8	8	27	27	22	22
2.1	4	4	4	4	0	0	0	0	4	4	4	4	2	2	2	2	10	10	10	10
2.2	4	4	4	4	1	1	1	1	4	4	3	3	2	2	2	2	11	11	10	10
2.3	3	3	3	3	0	0	0	0	3	3	3	3	1	1	1	1	7	7	7	7
2.4	4	4	4	4	0	0	0	0	2	2	2	2	1	1	1	1	7	7	7	7
2.6	2	2	2	2	0	0	0	0	3	3	3	[illegible]	1	1	1	1	6	6	6	6
2.7	3	3	3	3	0	0	0	0	3	3	3	3	1	1	1	1	7	7	7	7
2.8	1	1	1	1	0	0	0	0	4	4	4	[illegible]	1	1	1	1	6	6	6	6
2.9	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	3	3	3	3
3.2	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	5	5	5	5
3.3	2	2	2	2	0	0	0	0	1	1	1	1	0	0	0	0	3	3	3	3
3.4	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2
3.6	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	[illegible]	1	1
3.7	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4.1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
5.2	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
Total	1065	318	264	374	413	105	60	61	1526	445	344	492	931	257	206	283	3935	1125	874	1210
> 1V	296	296	256	263	78	78	45	45	431	431	339	352	241	241	196	199	1046	1046	836	859

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Table 3-2
Braidwood Unit 1 February 1995 EOC - 5A
ODSCC Indication Axial Distribution

Tube Support Plate	Steam Generator A				Steam Generator B				Steam Generator C				Steam Generator D				Composite			
	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	Number of Indications	Maximum Voltage	Average Voltage	Average # Growth	Number of Indications	Maximum Voltage	Average Voltage	Average # Growth
3H	535	2.89	0.81	0.28	218	2	0.76188	0.168266	834	5.13	0.92	0.29	509	3.53	0.88	0.31	2194	5.13	0.87	0.28
5H	330	3.39	0.90	0.37	181	3.13	0.74294	0.245125	380	3.64	0.78	0.24	281	3.17	0.82	0.28	1132	3.64	0.82	0.29
7H	137	2.65	0.83	0.56	28	[illegible]	0.5825	0.129288	156	2.83	0.76	0.25	97	2.20	0.77	0.29	421	2.83	0.77	0.27
8H	45	3.38	0.83	0.34	4	0.48	0.4825	0.075	40	2.58	0.77	0.31	42	0.93	0.78	0.31	131	2.57	0.78	0.31
9H	6	4.83	1.02	0.57	2	0.32	0.3	0.055	12	1.22	0.65	0.65	19	0.93	0.87	0.29	41	4.00	0.72	0.32
10H	2	0.78	0.82	0.18	0	-	-	-	1	0.85	0.85	0.36	2	0.45	0.43	0.27	5	0.85	0.59	0.20
11H	1	1.11	1.11	0.09	0	-	-	-	0	-	-	-	1	0.62	0.52	0.08	2	1.11	0.82	0.08
9C	1	0.85	0.85	0.29	0	-	-	-	0	-	-	-	0	-	-	-	1	0.85	0.85	0.29
10C	3	0.83	0.49	0.11	1	0.41	0.41	0.01	0	-	-	-	0	-	-	-	4	0.83	0.47	0.32
11C	3	0.84	0.69	0.18	1	0.32	0.32	0.01	0	-	-	-	0	-	-	-	4	0.95	0.65	0.22
Total	1088				413				1526				931				3936			

1994 to 1995 growth rates are based on 1994 bobbin voltage reevaluated in 1995.

Table 3-3
Braidwood Unit 1 February 1995 EOC - 5A
Average Voltage Growth
Composite of All Steam Generator Data

	Number of Indications	Average BOC Voltage	Average DV Growth/Cycle	Cycle EFPY	Average DV Growth/EFPY	% Growth per Cycle	% Growth per EFPY
	Cycle 5A 3/94 to 2/95						
Entire Voltage Range	3884#	0.56	0.28	0.714	0.40	51	72
V BOC < .75	3085#	0.46	0.25		0.35	54	75
V>=.75	799#	0.92	0.42		0.59	46	64
	Cycle 4 9/92 - 3/94						
Entire Voltage Range	2654	0.48	0.26	1.147	0.23	54	47
V BOC < .75	2289	0.41	0.29		0.25	71	62
V>=.75	365	0.92	0.13		0.11	14	12
	Cycle 3 4/91 to 9/92						
Entire Voltage Range	167	0.62	0.62	1.12	0.55	100	89
V BOC < .75	145	0.43	0.65		0.58	151	135
V>· .75	22	0.92	0.42		0.38	46	41

Includes only those indications for which 1994 to 1995 growth was calculated.

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Table 3-4
Braidwood Unit 1 February 1995
Average Voltage Growth for Cycle 5A

	Number of indications	Average BOC Voltage	Average ΔV Growth/Cycle	Cycle EFPY	Average ΔV Growth/EFPY	% Growth per Cycle	% Growth per EFPY
	Composite of All Steam Generators						
Entire Voltage Range	3884	0.56	0.26	0.714	0.40	51	72
V BOC < .75	3085	0.46	0.25		0.35	54	75
V>=.75	799	0.92	0.42		0.59	46	64
	Steam Generator A						
Entire Voltage Range	1039	0.52	0.32	0.714	0.45	61	86
V BOC < .75	849	0.43	0.29		0.41	67	94
V>=.75	190	0.93	0.45		0.64	49	68
	Steam Generator B						
Entire Voltage Range	410	0.55	0.19	0.714	0.27	35	49
V BOC < .75	332	0.46	0.17		0.24	38	53
V>=.75	77	0.96	0.28		0.39	29	41
	Steam Generator C						
Entire Voltage Range	1514	0.59	0.27	0.714	0.38	46	65
V BOC < .75	1141	0.48	0.23		0.32	46	65
V>=.75	373	0.91	0.42		0.59	46	65
	Steam Generator D						
Entire Voltage Range	921	0.54	0.30	0.714	0.42	56	78
V BOC < .75	763	0.46	0.27		0.38	58	81
V>=.75	158	0.90	0.44		0.62	50	70

Table 3 - 6
Braidwood Unit 1
Signal Growth Statistics on EFPY Basis

Delta Volts Bin	Steam Generator A			Steam Generator B			Steam Generator C			Steam Generator D			Cumulative			Hybrid#	
	1992 to 1994	1994 to 1995		1992 to 1994	1994 to 1995		1992 to 1994	1994 to 1995		1992 to 1994	1994 to 1995		1992 to 1994	1994 to 1995		1994 to 1995	
	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	No of Obs	CPDF
-0.4		5	0.003		3	0.004		1	0.001		1	0.001		6	0.002	3	0.003
-0.3		6	0.006		5	0.017		5	0.004		3	0.004		17	0.006	4	0.008
-0.2		11	0.010		7	0.034		15	0.014		13	0.017		39	0.018	11	0.015
-0.1		49	0.066		30	0.107		60	0.059		35	0.051		181	0.066	45	0.064
0.0	0.327	166	0.203	0.276	81	0.305	0.263	211	0.190	0.390	137	0.199	0.387	563	0.211	144	0.203
0.1	0.500	138	0.338	0.520	98	0.536	0.439	301	0.357	0.633	129	0.330	0.488	598	0.365	150	0.326
0.2	0.607	156	0.486	0.710	65	0.676	0.580	332	0.551	0.668	114	0.443	0.582	564	0.510	156	0.486
0.3	0.690	107	0.586	0.817	41	0.776	0.733	200	0.667	0.736	100	0.544	0.681	467	0.639	107	0.588
0.4	0.688	92	0.676	0.915	33	0.839	0.828	161	0.753	0.813	87	0.630	0.726	363	0.722	95	0.677
0.5	0.726	72	0.747	0.948	17	0.875	0.880	97	0.817	0.851	79	0.710	0.830	265	0.790	73	0.746
0.6	0.771	48	0.795	0.957	11	0.916	0.924	62	0.863	0.898	43	0.753	0.866	184	0.838	46	0.792
0.7	0.816	48	0.830	0.957	13	0.941	0.935	49	0.895	0.931	46	0.799	0.899	169	0.854	48	0.838
0.8	0.856	30	0.877	0.963	4	0.951	0.971	35	0.923	0.930	35	0.834	0.905	105	0.881	30	0.876
0.9	0.881	17	0.893	0.971	3	0.956	0.977	30	0.943	0.952	52	0.886	0.940	64	0.926	17	0.882
1.0	0.906	18	0.910	0.974	5	0.970	0.986	18	0.955	0.961	12	0.898	0.951	56	0.941	16	0.899
1.1	0.920	31	0.931	0.976	6	0.978	0.989	14	0.964	0.969	16	0.914	0.963	49	0.951	35	0.930
1.2	0.938	15	0.943	0.978	1	0.980	0.991	8	0.970	0.975	10	0.964	0.971	35	0.962	10	0.949
1.3	0.947	11	0.954	0.980	5	0.988	0.994	7	0.974	0.980	9	0.973	0.974	36	0.966	11	0.959
1.4	0.951	9	0.962	0.984	3	0.985	0.994	8	0.980	0.986	6	0.977	0.978	35	0.976	9	0.962
1.5	0.958	7	0.966	0.986	4	0.993	0.995	6	0.983	0.982	4	0.982	0.983	17	0.980	7	0.968
1.6	0.963	4	0.973	0.989	0	0.993	0.997	5	0.984	0.983	1	0.983	0.985	6	0.982	4	0.975
1.7	0.968	5	0.975	0.989	1	0.995	0.998	4	0.987	0.984	2	0.985	0.985	13	0.985	3	0.977
1.8	0.972	6	0.976	0.985	0	0.995	0.999	3	0.987	0.984	3	0.986	0.985	4	0.986	8	0.977
1.9	0.974	6	0.980	0.993	1	0.996	0.999	1	0.990	0.987	7	0.990	0.986	10	0.986	6	0.985
2.0	0.976	5	0.982	0.995	0	0.996	0.998	1	0.990	0.987	4	0.985	0.988	2	0.988	1	0.986
2.1	0.979	4	0.988	0.995	0	0.996	0.999	1	0.990	0.987	3	0.990	0.990	5	0.989	4	0.988
2.2	0.982	0	0.988	0.993	0	0.996	1.000	9	0.991	0.987	2	0.990	0.990	5	0.992	6	0.985
2.3	0.984	1	0.989	0.996	1	0.998		3	0.993	0.989	1	0.995	0.990	0	0.994	5	0.989
2.4	0.987	5	0.993	0.997	0	0.998		3	0.994	0.989	6	0.995	0.991	1	0.994	3	0.991
2.5	0.988	1	0.995	0.994	0	0.998		2	0.995	0.990	1	0.996	0.991	4	0.993	1	0.972
2.6	0.989	0	0.995	0.996	0	0.998		3	0.997	0.985	4	0.996	0.994	2	0.995	0	0.992
2.7	0.991	1	0.996	0.996	0	0.998		1	0.997	0.991	0	0.996	0.993	3	0.995	1	0.995
2.8	0.991	4	0.996	0.996	0	0.998		0	0.997	0.991	2	0.998	0.994	1	0.997	0	0.999
3.0	0.994	2	0.998	0.998	1	1.000		1	0.998	0.993	6	0.998	0.996	4	0.996	2	0.995
3.1	0.996	0	0.998	0.998				0	0.998	0.994	2	1.000	0.997	3	0.996	4	0.995
3.3	0.996	1	0.997	0.999				1	0.999	0.994			0.997	2	0.995	1	0.996
3.4	0.996	1	0.998	1.000				0	0.999	0.996			0.998	0	0.996	1	0.997
3.7	0.996	1	0.999					0	0.999	0.996			0.998	0	0.998	4	0.998
3.9	0.998	0	0.999					1	0.999	0.997			0.999	2	1.000	0	0.998
4.3	0.997	1	1.000					0	0.999	0.997			0.999	1	1.000	1	0.999
5.7	0.998							1	1.000	0.997			0.999			1	1.000
6.0	1.000									0.997			0.999				
7.5										0.999			0.999				
8.0										1.000			1.000				
Total		1839			488			1584			993			3886		1840	

Based on steam generator A distribution plus largest growth for steam generator C

Table 3 - 6
Braidwood Unit 1
Signal Growth Distibutions Assumed for Limiting Case Projections

Delta Volts Bin	CYCLE 4				CYCLE 5A	
	Steam Generator A		Steam Generator D		Hybrid S/G	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	5	0.007	0	0.000	0	
-0.4	6	0.016	5	0.007	0	
-0.3	14	0.037	18	0.034	0	
-0.2	26	0.075	32	0.081	4	0.004
-0.1	48	0.146	49	0.152	9	0.013
0.0	62	0.237	83	0.274	54	0.064
0.1	64	0.331	86	0.400	186	0.243
0.2	89	0.462	115	0.568	226	0.461
0.3	63	0.554	86	0.694	172	0.626
0.4	60	0.643	58	0.779	111	0.733
0.5	33	0.691	40	0.837	74	0.804
0.6	29	0.734	20	0.867	52	0.854
0.7	30	0.778	24	0.902	38	0.890
0.8	26	0.816	13	0.921	26	0.915
0.9	21	0.847	10	0.936	27	0.941
1.0	19	0.875	11	0.952	13	0.954
1.1	14	0.896	4	0.958	13	0.966
1.2	15	0.918	6	0.966	6	0.972
1.3	10	0.932	3	0.971	5	0.977
1.4	6	0.941	3	0.975	5	0.982
1.5	6	0.950	3	0.980	2	0.984
1.6	2	0.953	0	0.980	4	0.988
1.7	3	0.957	2	0.982	1	0.988
1.8	3	0.962	0	0.982	3	0.991
1.9	3	0.966	0	0.982	1	0.992
2.0	1	0.968	1	0.984	1	0.993
2.1	4	0.974	0	0.984	0	0.993
2.2	1	0.975	2	0.987	2	0.995
2.3	3	0.979	0	0.987	0	0.995
2.4	0	0.979	0	0.987	1	0.996
2.5	2	0.982	0	0.987	1	0.997
2.6	1	0.984	2	0.990	0	0.997
2.7	1	0.985	0	0.990	1	0.998
2.8	1	0.987	0	0.990	0	0.998
2.9	1	0.988	0	0.990	0	0.998
3.1	2	0.991	1	0.991	1	0.999
3.3	0	0.991	1	0.993	0	0.999
3.5	3	0.996	0	0.993	0	0.999
3.7	0	0.996	1	0.994	0	0.999
3.9	0	0.996	1	0.996	0	0.999
4.2	0	0.996	0	0.996	1	1.000
4.3	0	0.996	1	0.997		
4.7	1	0.997	0	0.997		
5.1	1	0.999	0	0.997		
6.7	1	1.000	0	0.997		
8.1			1	0.999		
9.8			1	1.000		
Total	680		683		1040	

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Table 3 - 7
Braidwood Unit 1 February 1995
Summary of Largest Voltage Growth Rates for BOC-5A to EOC-5A

Steam Generator				Bobbin Data			RPC	1994 Bobbin
	Row	Col	Elevation	EOC - 5A	BOC - 5A	Growth	Confirmed	Call
C	15	73	3H	5.13	1.01	4.12	Y	ODI
A	3	48	9H	4.03	1.01	3.02	Y	ODI
C	9	105	5H	3.64	0.85	2.79	Y	ODI
A	45	54	5H	3.29	0.63	2.66	Y	ODI
A	10	94	5H	3.39	0.84	2.45	Y	ODI
A	44	60	5H	3.24	0.89	2.35	Y	ODI
C	27	78	3H	3.22	0.88	2.34	Y	ODI
D	13	6	3H	3.53	1.25	2.28	Y	ODI
D	41	54	3H	3.20	0.99	2.21	Y	ODI
C	31	73	5H	3.17	0.97	2.20	Y	ODI
A	12	19	5H	3.12	0.95	2.17	Y	ODI
B	25	25	5H	3.13	0.97	2.16	Y	ODI
A	41	72	3H	2.52	0.36	2.16	Y	NDD
D	35	62	5H	3.17	1.12	2.05	Y	ODI
D	13	4	3H	2.81	0.79	2.02	Y	NDD
C	21	78	3H	2.72	0.74	1.98	Y	ODI
A	1	103	8H	2.57	0.59	1.98	Y	ODI
D	16	76	3H	2.65	0.69	1.96	Y	ODI
C	1	111	7H	2.83	0.91	1.92	Y	ODI
C	13	28	7H	2.72	0.84	1.88	Y	ODI
A	23	9	3H	2.65	0.80	1.85	Y	ODI
C	27	104	8H	2.51	0.70	1.81	Y	ODI
D	28	51	5H	2.80	1.00	1.80	Y	ODI
C	20	9	3H	2.64	0.85	1.79	Y	ODI
A	40	63	7H	2.65	0.87	1.78	Y	NDD
A	25	85	5H	2.07	0.29	1.78	Y	NDD
A	48	35	5H	2.80	1.03	1.77	Y	ODI
C	17	37	3H	2.56	0.79	1.77	Y	ODI
C	35	81	5H	2.77	1.01	1.76	Y	ODI
C	16	6	3H	2.26	0.55	1.71	Y	ODI
D	22	39	3H	2.59	0.90	1.69	Y	ODI
A	8	109	8H	2.38	0.70	1.68	Y	ODI
C	9	92	3H	2.67	1.03	1.64	Y	ODI
D	13	77	5H	2.33	0.70	1.63	Y	ODI
C	22	42	3H	2.39	0.79	1.60	Y	ODI
C	22	32	3H	2.38	0.79	1.59	Y	ODI
C	4	93	8H	2.56	0.98	1.58	Y	ODI
D	18	88	3H	2.09	0.52	1.57	Y	NDD
A	20	95	5H	2.32	0.77	1.55	Y	NDD
A	36	71	5H	2.68	1.15	1.53	Y	ODI
A	33	91	5H	2.08	0.55	1.53	Y	NDD
A	3	79	3H	2.89	1.37	1.52	Y	ODI
C	30	86	5H	2.61	1.11	1.50	Y	ODI
A	10	59	3H	2.11	0.63	1.48	Y	NDD
C	11	106	3H	2.27	0.80	1.47	Y	ODI
C	32	75	3H	2.19	0.77	1.42	Y	ODI
A	5	71	5H	2.30	0.89	1.41	Y	ODI
A	3	100	3H	2.39	1.30	1.38	Y	ODI
A	21	75	5H	2.15	0.76	1.39	Y	ODI
D	45	51	3H	1.64	0.25	1.39	Y	NDD
B	15	101	5H	2.14	0.77	1.37	Y	NDD
A	21	63	5H	1.88	0.51	1.37	Y	NDD
A	40	64	5H	1.92	0.55	1.37	Y	ODI

Figure 3-1
Braidwood Unit-1 February 1995 EOC-5A
Measured Bobbin Voltage Distributions

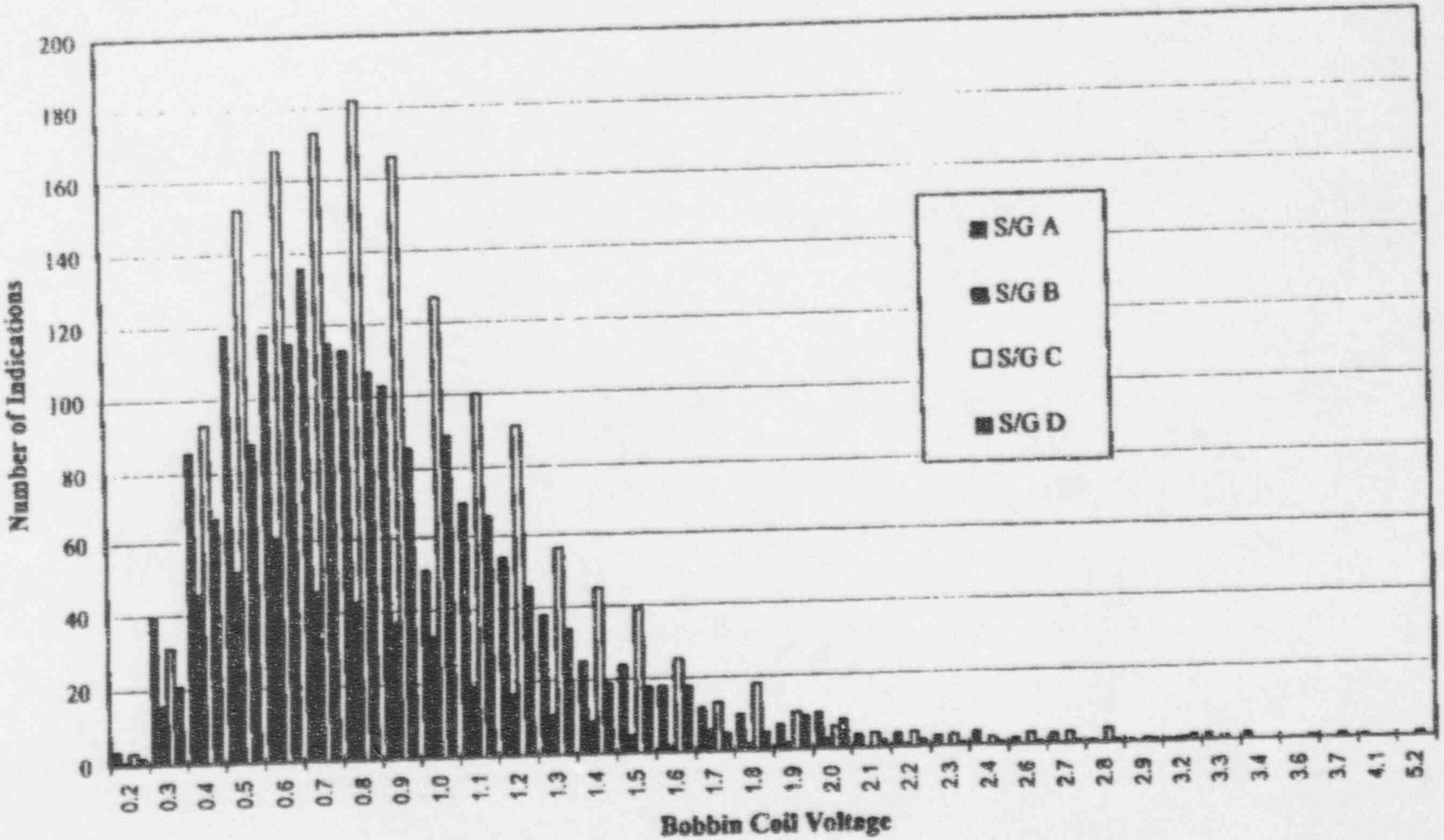

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Figure 3-2
Braidwood Unit-1 February 1995 EOC-5A
Bobbin Voltage Distribution for Plugged Tubes

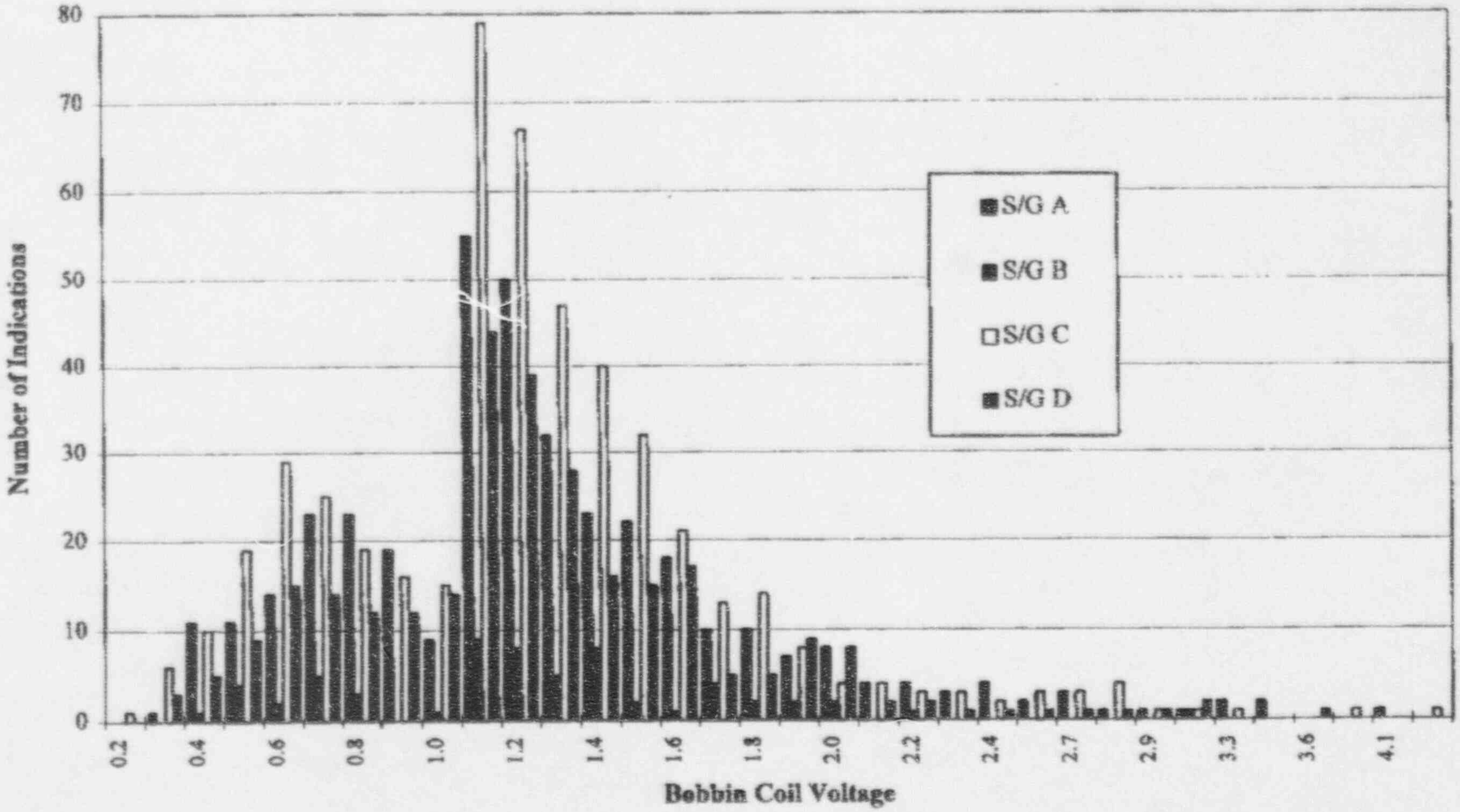

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Figure 3-3
Braidwood Unit-1 February 1995
Bobbin Coil Voltage Distribution for Tubes Returned to Service for Cycle 5B

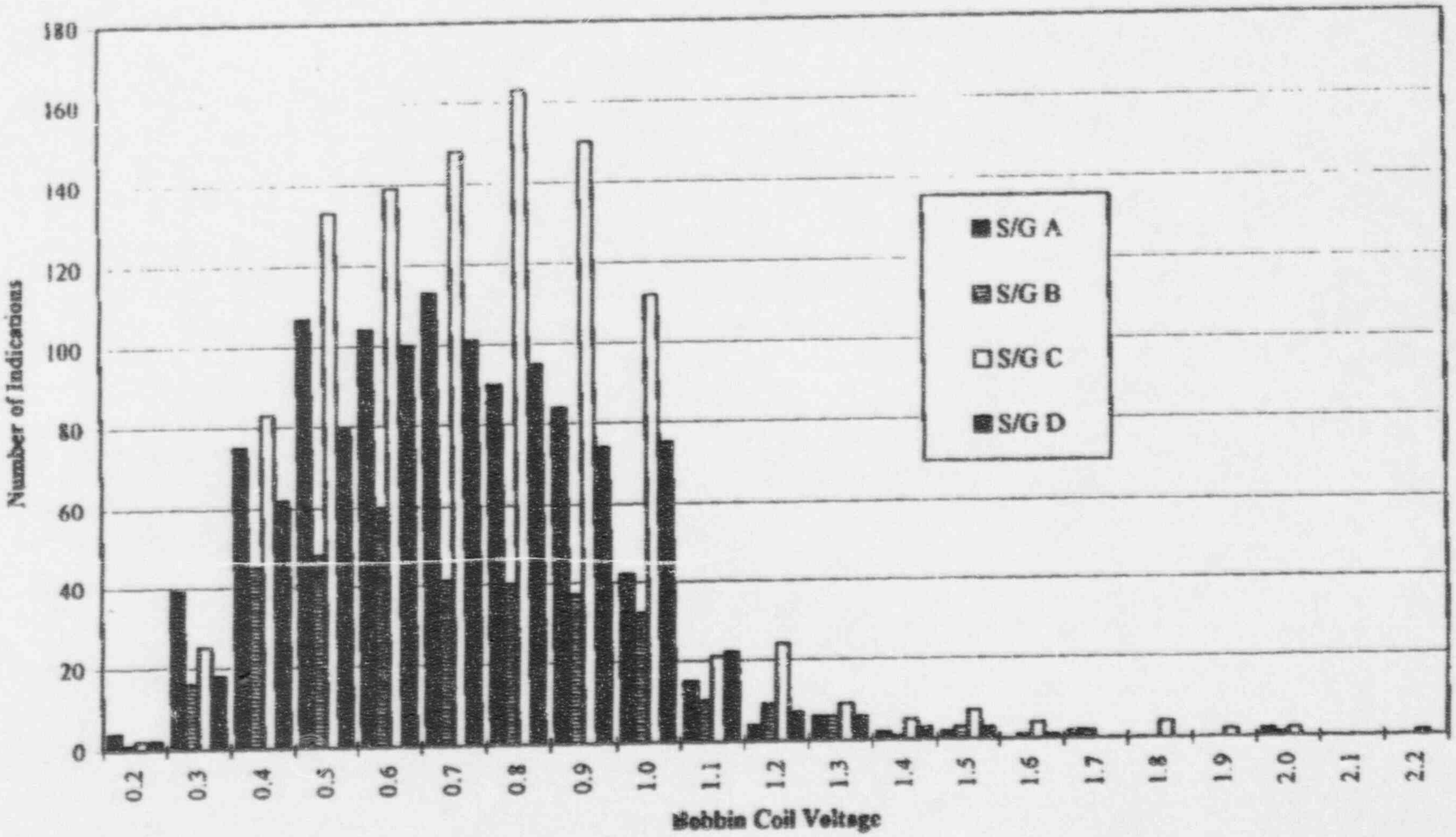

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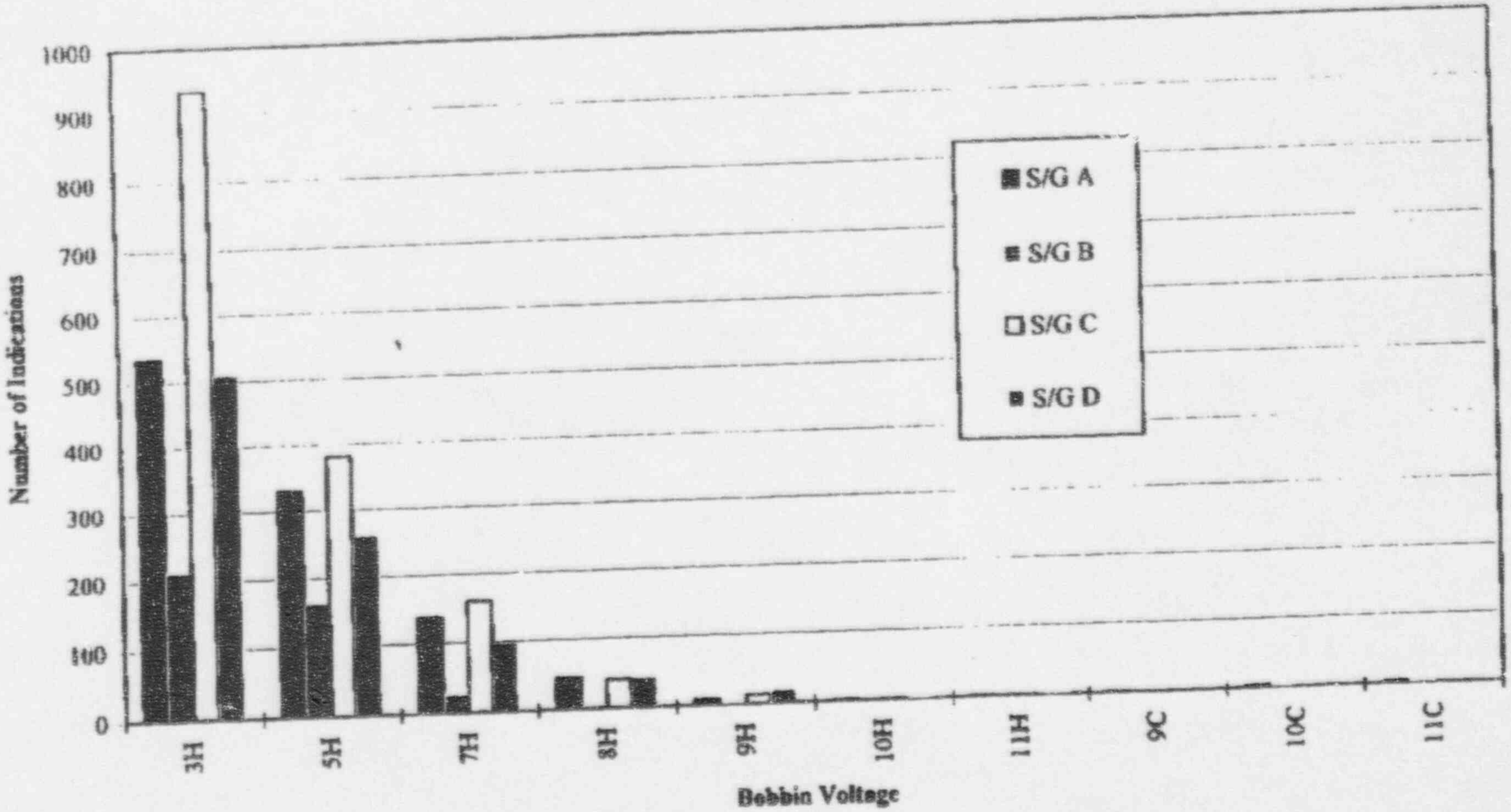
Figure 3-4
Braidwood Unit - 1 February 1995
EOC - 5A ODSCC Axial Distributions



GROWTH KWOOSCC TSP SUM CHRT

4.0 DATA BASE APPLIED FOR IPC CORRELATIONS

The database used for the IPC correlations that are applied in the analyses of this report are consistent with the Braidwood-1 SER for Cycle 5 and the Byron-1 SER (with the addition of the Braidwood-1 and Byron-1 1995 pulled tube results) and is documented in Reference 8.2. Model boiler specimen 598-1 is excluded from the 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 ≤ 60% and there are ≤ 2 remaining uncorroded ligaments. Plant S pulled tube indication R28C41 is included in the leak rate correlation at a SLB leak rate of 2496 liters/hr consistent with NRC recommendations. Accordingly, this 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 and is referred to as the NRC database, in contrast with the EPRI database which excludes several outlier data points.

5.0 SLB ANALYSIS METHODS

Monte Carlo analyses are used to calculate projected voltage distributions and to calculate the SLB leak rates and tube burst probabilities for both actual and projected voltage distributions. The Monte Carlo analyses account for parameter uncertainty and the methodology complies with with the Braidwood Unit 1 SER and is described in Reference 8.1 and is also documented in the Westinghouse generic methods report of Reference 8.2.

Monte Carlo analyses include POD adjustments, voltage growth and NDE uncertainties in the projected analyses while only NDE uncertainties are included in the tube leak and burst analyses for the actual voltage distribution. 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 calculations were performed for this outage evaluation - the first set for the Return-to-Power (RTP) evaluation in March 1995 and the second set for this 90 Day evaluation. The 90 Day report calculations are based on up-dated tube leak rate and burst probabilities which incorporate new data from Byron/Braidwood but do not

effect the methodology that has been documented by Westinghouse and approved by the NRC.

6.0 BOBBIN VOLTAGE DISTRIBUTIONS

6.1 PROBABILITY OF DETECTION (POD)

The number of indications assumed in the analysis to predict tube leak rate and burst probability 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. 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.

The draft NRC generic letter (Reference 8.3) requires the application of a POD = 0.6 to define the BOC distribution for the EOC voltage projections, unless an alternate POD is approved by the NRC. A POD = 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 APC/IPC experience. There are no deplugged tubes returned to service at BOC-5B.

6.2 CALCULATION OF VOLTAGE DISTRIBUTIONS

The overall growth rates for the previous two operating periods, represented by the cumulative probability distribution functions on Figure 6-1, confirm the discussion in Section 3.2 that the 1994-1995 operation (cycle 5A) growth rates exceed those of the 1992-1994 cycle 4. For these two operating periods, SG A rates exceed those of the other three SG, as indicated by Figures 6-2 and 6-3.

To conservatively predict the IPC voltage distribution at EOC-5A, the SG A growth rate was applied to the BOC-5A tube indication conditions in SGs A, B,and C. The the SG D growth rate was applied to the BOC-5A tube conditions in SG D.

To conservatively predict the IPC voltage distribution at EOC-5B, the growth projections are based on rates determined for a hybrid steam generator, defined in Section 3.2, with growth characteristics which envelope the growth data developed from the EOC-5A ECT inspections. This hybrid growth rate will be used in the prediction calculations for cycle 5B. In Table 3-1, SG C is tentatively identified as the limiting SG with 431 indications > 1.0 volt at EOC-5A, of which 352 have been plugged and 79 returned to service for cycle 5B operation.

The operating periods used in the voltage projection calculations are:

Cycle 4	-		-	418.94 EFPD.
Cycle 5A	-	BOC-5 to MOC-5	-	260.68 EFPD.
Cycle 5B	-	MOC-5 to EOC-5	-	179.34 EFPD.

6.3 PROJECTED BOC-5A TO EOC-5A VOLTAGE DISTRIBUTIONS

The methodology used in the projection of bobbin voltage frequency predictions is described in Reference 8.2 and is essentially the same as that used in Reference 8.1 for the cycle 5 predictions of 1994. Analyses were performed to determine projected EOC-5A bobbin voltage distributions, based on the BOC-5A conditions summarized in Table 6-1 and the 1992 - 1994 (cycle 4) cumulative distributions summarized in Table 3-6. The actual EOC-5A bobbin voltage distributions and the corresponding EOC-5A projections are summarized on Table 6-1 and are also shown on Figures 6-4 for the individual steam generators.

6.4 COMPARISON OF ACTUAL AND PROJECTED EOC-5A VOLTAGES

A review of Table 6-1 and Figure 6-4 provides a comparison of the actual EOC-5A bobbin indications with the corresponding predictions based on a constant POD of 0.6. These data indicate the following trends:

a) The POD = 0.6 tends to over-predict the tube defect population and is predominantly conservative.

b) A voltage-based POD might provide a more accurate prediction for IPC/APC performance.

6.5 PROJECTED EOC-5B VOLTAGE DISTRIBUTIONS

Using the methodology previously described in this report, analyses were performed to predict the performance of the Braidwood Unit 1 steam generators at EOC-5B, in a manner similar to that used for EOC-5A. The IPC voltage distribution projected from BOC-5B to EOC-5B is summarized on Table 6-2 for POD = 0.6. As anticipated, the limiting steam generator is SG C with 2051 indications predicted for POD = 0.6 These results are shown graphically on Figures 6-5.

Table 6 - 1 (Page 1 of 2)
Braidwood Unit 1 February 1995
Comparison of Predicted and Actual EOC-5A Voltage Statistics

	Steam Generator A					Steam Generator B				
	EOC - 4		BOC - 5A	EOC - 5A		EOC - 4		BOC - 5A	EOC - 5A	
				Prediction	Actual				Prediction	Actual
Delta Volts Bin	No. of Ind.	Plugged No. of Ind.	POD=.6 No. of Ind.	POD=.6 No. of Ind.	No. of Ind.	No. of Ind.	Plugged No. of Ind.	POD=.6 No. of Ind.	POD=.6 No. of Ind.	No. of Ind.
0.1	1	0	1.7	0.59	0	0	0	0.0	0.06	0
0.2	6	0	10.0	4.46	4	5	0	8.3	3.00	1
0.3	49	0	81.7	27.75	40	21	0	35.0	13.48	16
0.4	64	5	101.7	49.85	86	51	1	84.0	33.25	46
0.5	92	5	148.3	76.99	118	43	0	71.7	44.20	52
0.6	92	8	145.3	92.99	118	48	0	80.0	51.75	61
0.7	68	6	107.3	94.59	136	27	0	45.0	49.14	66
0.8	45	2	73.0	88.21	113	25	2	39.7	45.86	43
0.9	51	8	77.0	83.34	103	23	0	38.3	41.28	37
1	44	6	67.3	76.60	51	3	0	5.0	33.11	33
1.1	34	33	23.7	64.21	70	6	4	6.0	25.69	19
1.2	25	22	19.7	51.46	54	6	4	6.0	20.03	17
1.3	25	25	16.7	41.06	38	2	0	3.3	15.50	11
1.4	14	14	9.3	32.50	25	2	1	2.3	11.58	9
1.5	11	10	8.3	25.52	24	0	0	0	8.47	5
1.6	9	9	6.0	20.46	18	2	2	1.3	6.27	2
1.7	13	13	8.7	16.74	12	0	0	0	4.81	6
1.8	8	8	5.3	13.87	10	2	2	1.3	3.76	2
1.9	7	7	4.7	11.47	7	0	0	0	3.02	2
2	6	6	4.0	9.72	10	0	0	0	2.56	3
2.1	5	5	3.3	8.34	4	2	1	2.3	2.20	0
2.2	8	8	3.3	7.17	4	0	0	0	1.95	1
2.3	3	3	2.0	6.09	3	0	0	0	1.71	0
2.4	1	1	0.7	5.12	4	0	0	0	1.51	0
2.5	4	4	2.7	4.28	0	1	0	1.7	1.34	0
2.6	2	2	1.3	3.55	2	0	0	0	1.16	0
2.7	1	1	0.7	2.94	3	0	0	0	0.97	0
2.8	0	0	0.0	2.47	1	1	1	0.7	0.74	0
2.9	0	0	0.0	2.14	1	0	0	0	0.57	0
3	3	3	2.0	1.94	0	0	0	0	0.44	0
3.1	3	3	2.0	1.80	0	0	0	0	0.33	0
3.2	0	0	0.0	1.70	1	0	0	0	0.00	1
3.3	2	2	1.3	1.60	2	0	0	0	0.25	
3.4	0	0	0	1.49	2	0	0	0	0.25	
3.5	2	2	1.3	1.28	0	0	0	0	0.26	
3.6	1	1	0.7	1.24	0	0	0	0	0.25	
3.7	0	0	0	1.13	0	1	1	0.7	0.24	
3.8	1	1	0.7	1.01	0	0	0	0	0.23	
3.9	0	0	0	0.92	0	0	0	0	0.82	
4	2	2	1.3	0.84	0	0	0	0	0	
4.1	0	0	0	0.77	1	0	0	0	0	
4.2	1	1	0.7	0.70		0	0	0	0	
4.3	0	0	0	0.66		1	1	0.7	0	
4.4	0	0	0	0.63					0	
4.5	0	0	0	0.63					0	
4.6	0	0	0	0.56					0.7	
4.7	0	0	0	0.53					0	
4.8	0	0	0	0.44					0.30	
4.9	0	0	0	0.35						
5	1	1	0.7	0.29						
5.1	0	0	0	0.25						
5.2	0	0	0	0.20						
5.3	0	0	0	0.15						
5.6	1	1	0.7	0						
8.4	0	0	0	0.70						
8.5	1	1	0.7	0						
8.9	0	0	0	0.30						
TOTAL	704	229	947.7	946.71	1065	272	20	433.3	433.05	413
> 1.0 V	194	189	134.3	351.34	296	26	17	26.3	117.92	71
> 2.7 V	18	18	12	26.84	8	3	3	2	5.38	1

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Table 6 - 1 (Page 2 of 2)
Braidwood Unit 1 February 1995
Comparison of Predicted and Actual EOC-5A Voltage Statistics

	Steam Generator C					Steam Generator D				
	EOC - 4		BOC - 5A	EOC - 5A		EOC - 4		BOC - 5A	EOC - 5A	
				Prediction	Actual				Prediction	Actual
Delta Volts Bin	No. of Ind.	Plugged No. of Ind	POD=.6 No. of Ind.	POD=.6 No. of Ind.	No. of Ind.	No. of Ind.	Plugged No. of Ind.	POD=.6 No. of Ind.	POD=.6 No. of Ind.	No. of Ind.
0.1	1	0	1.7	0.60	0	0	0	0	0.03	0
0.2	7	0	11.7	3.00	2	3	1	4.0	2.56	2
0.3	51	0	85.0	31.51	21	21	0	51.7	22.36	21
0.4	124	4	202.7	81.77	93	83	1	137.3	65.50	67
0.5	156	7	253.0	129.88	152	111	6	179.0	108.56	89
0.6	160	5	261.7	163.62	168	107	6	172.5	122.08	115
0.7	142	5	228.7	177.44	173	93	12	143.0	136.42	113
0.8	117	1	194.0	177.29	182	68	1	112.3	124.09	107
0.9	92	10	143.3	164.85	166	38	1	62.3	101.97	86
1	64	7	99.7	143.34	127	34	1	55.7	80.78	89
1.1	41	33	36.2	115.90	100	41	36	32.3	61.31	66
1.2	31	29	22.7	90.30	91	18	17	15.6	43.76	46
1.3	18	17	13.0	70.39	36	14	13	10.3	30.35	34
1.4	22	17	19.7	54.96	43	9	9	6.6	21.10	19
1.5	8	7	6.3	41.70	39	6	5	5.0	14.85	18
1.6	7	6	3.7	31.14	25	4	3	3.7	10.80	18
1.7	3	3	2.0	23.25	13	6	6	4	8.23	2
1.8	3	3	2.0	17.58	18	3	2	2.0	6.52	3
1.9	3	3	2.0	15.63	10	4	4	2.7	5.25	9
2	2	2	1.3	10.91	6	3	3	2.0	4.24	8
2.1	1	1	0.7	8.87	4	0	0	0	3.39	2
2.2	3	3	2.0	7.34	4	4	4	2.7	2.72	2
2.3	0	0	0	6.19	3	1	1	0.7	2.26	1
2.4	1	1	0.7	5.24	2	0	0	0	1.91	1
2.5	1	1	0.7	4.44	0	1	1	0.7	1.64	0
2.6	0	0	0	3.70	3	1	1	0.7	1.46	1
2.7	0	0	0	2.99	3	0	0	0	0.00	1
2.8	1	1	0.7	0.00	4	1	1	0.7	1.28	1
2.9				1.75	1	1	1	0.7	1.21	1
3				1.29	0	0	0	0	1.13	0
3.1				0.94	0	0	0	0	1.01	0
3.2				0.73	1	1	1	0.7	0.85	2
3.3				0.64	1	1	1	0.7	0.70	0
3.4				0.63	0	0	0	0	0.59	0
3.5				0.64	0	0	0	0	0.50	0
3.6				0.63	0	0	0	0	0.43	1
3.7				0.48	1	1	1	0.7	0.40	
3.8				0.52	0	0	0	0	0.39	
3.9				0.45	0	1	1	0.7	0.38	
4				0.39	0	1	1	0.7	0.38	
4.1				0.33	0	0	0	0	0.36	
4.2				0.82	0	0	0	0	0.34	
4.3				0	0	1	1	0.7	0.30	
4.4				0	0	0	0	0	0.26	
4.5				0	0	0	0	0	0.22	
4.6				0	0	0	0	0	0.19	
4.7				0.7	0	0	0	0	0.15	
4.8				0	0	0	0	0	0.12	
4.9				0.3	0	0	0	0	0.11	
5					0	0	0	0	0.09	
5.1					0	1	1	0.7	0.22	
5.2					1	0	0	0	0.19	
5.3						0	0	0	0.17	
5.4						0	0	0	0.15	
5.5						0	0	0	0.15	
5.6						0	0	0	0.13	
5.7						0	0	0	0.13	
5.8						0	0	0	0.15	
5.9						0	0	0	0.15	
6						0	0	0	0.15	
6.1						0	0	0	0.15	
6.2						0	0	0	0.15	
6.3						0	0	0	0.13	
6.6						0	0	0	0.91	
8.9						1	1	0.7	0	
10.5						1	1	0.7	0	
10.6									0.70	
10.9									0.30	
TOTAL	1059	168	1597.0	1594.67	1526	694	145	1012.2	1010.33	931
> 1.0 V	145	126	115.7	519.57	421	126	116	94.5	235.16	241
> 2.7 V	1	1	0.67	11.34	9	11	11	7.7	15.29	5

Table 6 - 2
Braidwood Unit-1 February 1995
Voltage Distribution Projection for EOC - 5B

Delta Volts Bin	Steam Generator A		Steam Generator B		Steam Generator C		Steam Generator D	
	BOC-5B	EOC-5B PREDICTION	BOC-5B	EOC-5B PREDICTION	BOC-5B	EOC-5B PREDICTION	BOC-5B	EOC-5B PREDICTION
	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	POD=.6 No. of Indications
0.1	0	0.01	0	0	0	0.01	0	0.01
0.2	4	1.6	0	0.45	3	1	2	0.8
0.3	40	15.51	1	6.18	31	11.05	21	7.93
0.4	86	47.44	16	23.25	93	44.09	67	31.8
0.5	118	89.7	46	44.36	152	99.06	88	66
0.6	118	125.82	52	61.99	168	153.62	115	101.19
0.7	136	150.71	61	70.32	173	193.85	115	128.96
0.8	113	161.67	48	70.48	182	222.59	107	144.01
0.9	103	158.2	43	67.7	186	237.41	86	145.53
1	51	140.25	37	62.47	127	229.15	99	138.07
1.1	70	114.17	33	53.18	100	197	66	121.13
1.2	54	89.22	19	41.79	91	155.91	46	96.54
1.3	38	66.73	17	31.71	56	119.66	34	72.39
1.4	25	52.44	11	23.67	46	91.21	19	53.37
1.5	24	39.88	9	17.46	39	69.28	19	39.46
1.6	18	30.43	5	12.62	25	52.64	18	22.33
1.7	12	23.38	2	9.55	13	38.67	5	21.66
1.8	10	18.05	6	7.25	18	29.95	5	15.86
1.9	7	14.17	2	0	10	22.95	9	11.87
2	10	11.36	2	4.24	6	17.75	8	9.25
2.1	4	9.2	3	3.25	4	13.57	2	7.34
2.2	4	7.38	0	2.45	4	10.29	2	5.67
2.3	3	5.87	1	1.8	3	7.78	1	4.26
2.4	4	4.64	0	1.27	2	5.95	1	3.16
2.5	0	3.69	0	0.9	0	4.65	0	2.38
2.6	2	2.96	0	0.64	3	3.73	1	1.85
2.7	3	2.39	0	0.46	3	3.1	1	1.49
2.8	1	0	0	0.34	4	2.63	1	1.22
2.9	1	1.6	0	0.79	1	0	1	1.02
3	0	1.32	0	0	0	1.84	0	0.89
3.1	0	1.11	0	0	0	1.5	0	0.76
3.2	1	0.96	0	0	1	1.2	2	0
3.3	2	0.87	1	0	1	0.95	0	0.59
3.4	2	0.8		0	0	0.77	0	0.52
3.5	0	0.72		0.7	0	0.62	0	0.86
3.6	0	0.6		0	0	0.5	1	0
3.7	0	0.49		0.3	1	0.4		0
3.8	0	0.71				0.83		0
3.9	0	0				0		0.7
4	0	0				0		0
4.1	1	0				0		0.3
4.3		0.7				0		
4.5		0.3				0		
5.3						0.7		
5.6						0.3		
TOTAL	1065	1399.04	413	621.78	1525	2046.07	931	1267.98
> 1.0 V	298	508.14	111	214.56	430	866.35	241	503.89
> 2.7 V	8	10.18	1	2.13	8	11.24	5	6.86

Figure 6 - 1
Braidwood Unit - 1
Cumulative Probability Distributions for Voltage Growth on EFPY Basis
Composite of All Four Steam Generators

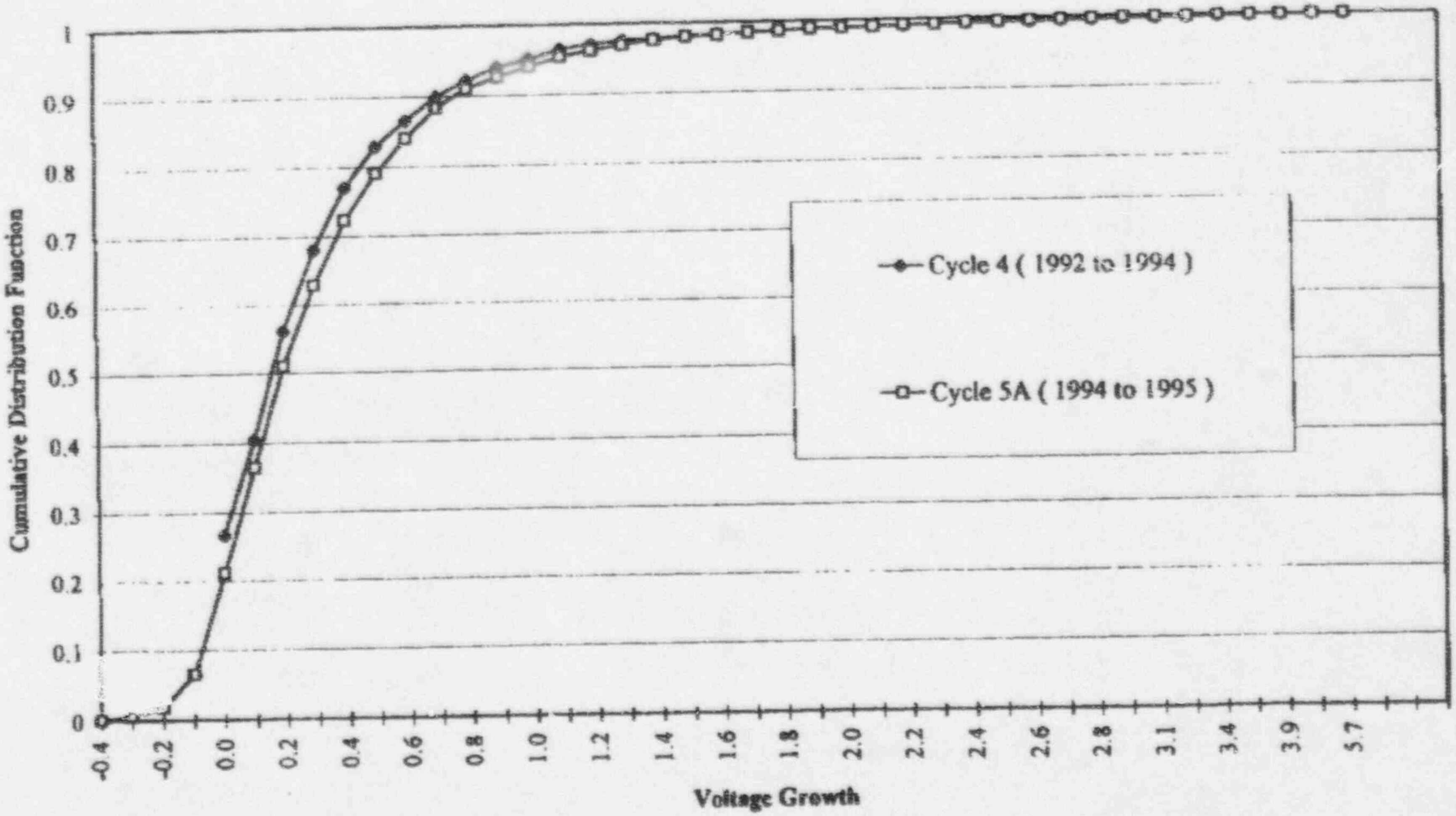

Figure 6 - 2
Braidwood Unit -1 Cycle 4 (1992 to 1994)
Cumulative Probability Distributions for Voltage Growth on EFPY Basis

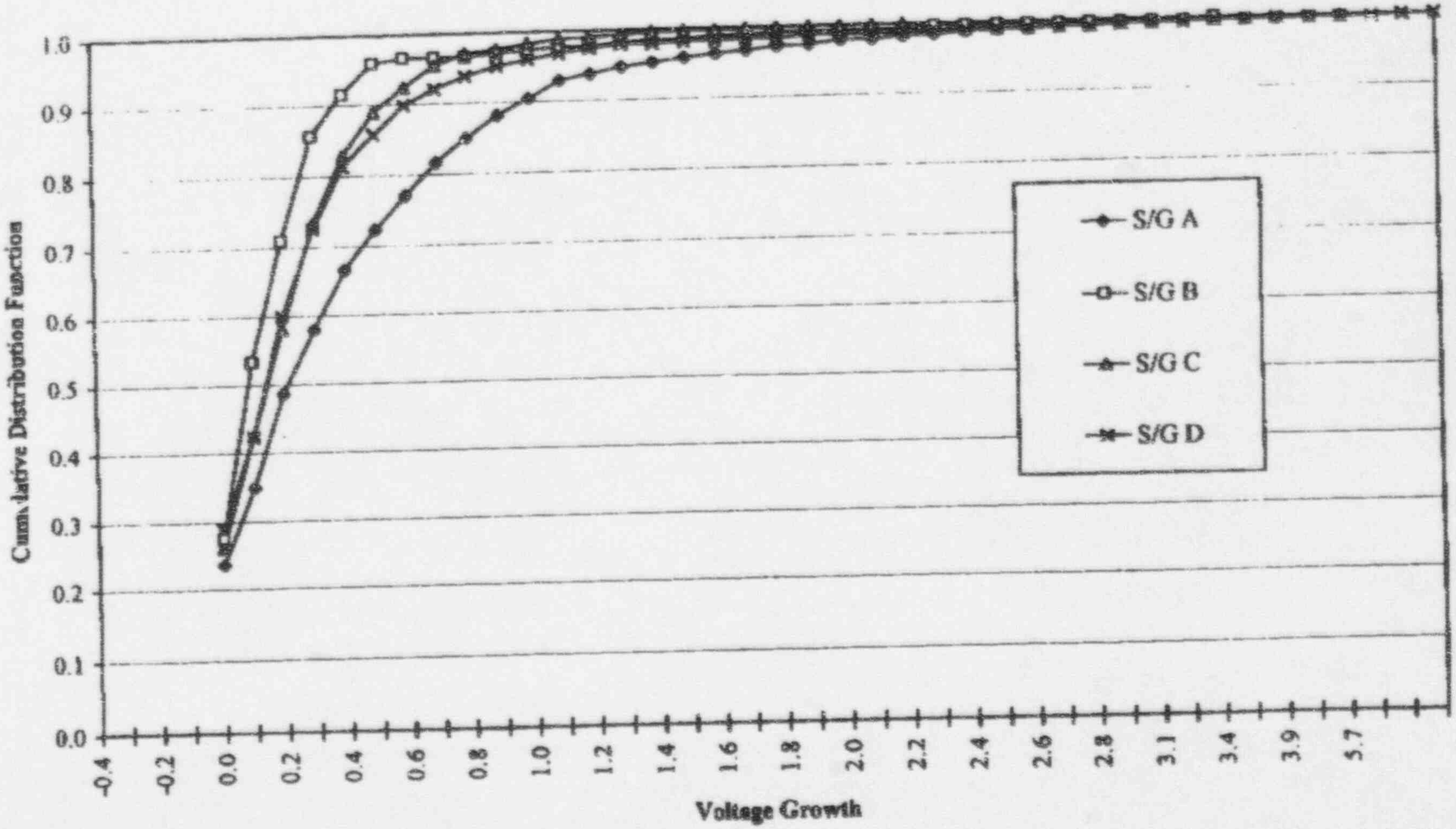

Figure 6 - 3
Braidwood Unit - 1 Cycle 5A (1994 to 1995)
Cumulative Probability Distributions for Voltage Growth on EFPY Basis

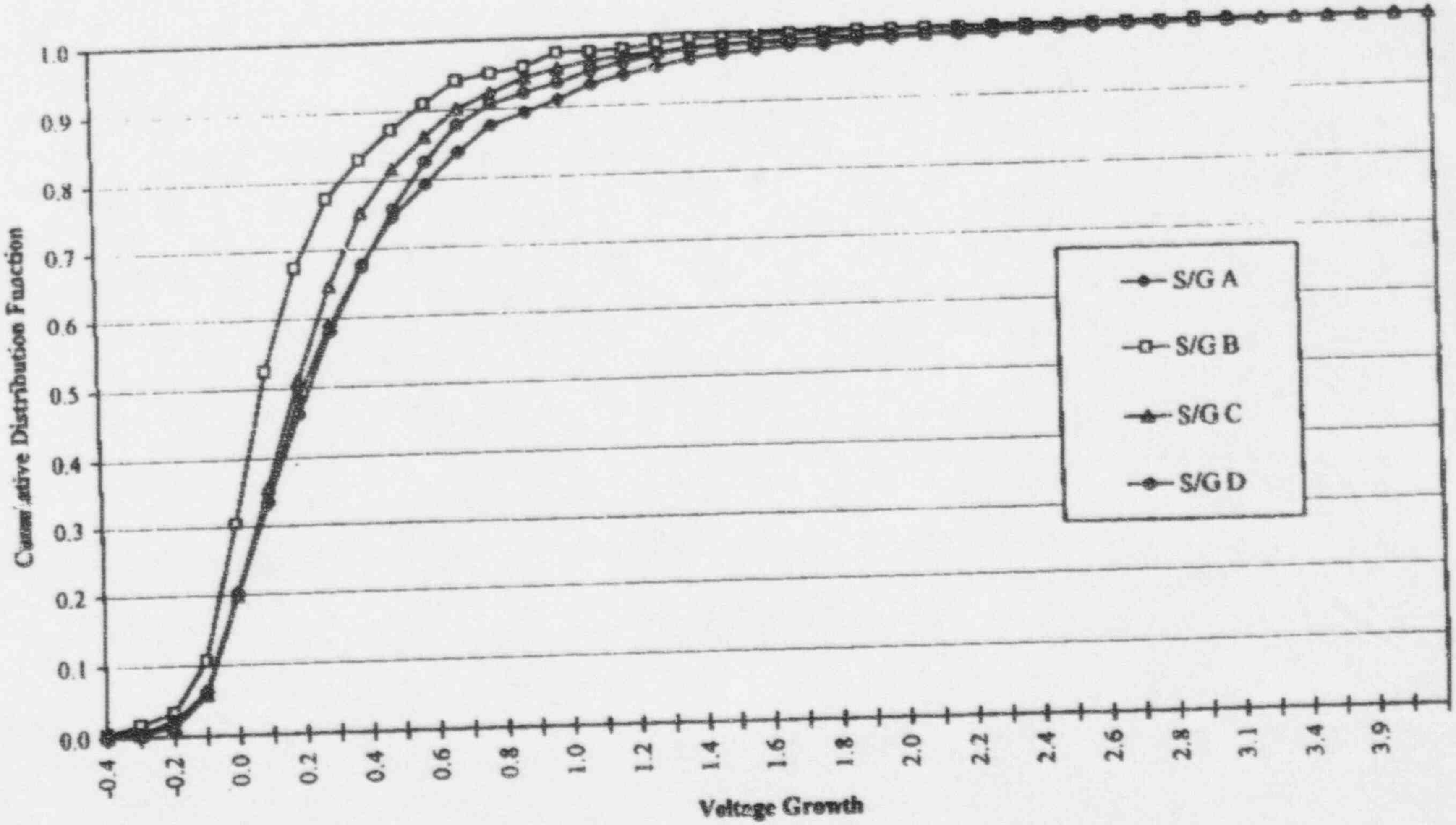

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Figure 6 - 4A

Braidwood Unit - 1

Comparison of Measured and Predicted EOC-5A Voltage Distributions

Steam Generator - A -- POD = 0.6

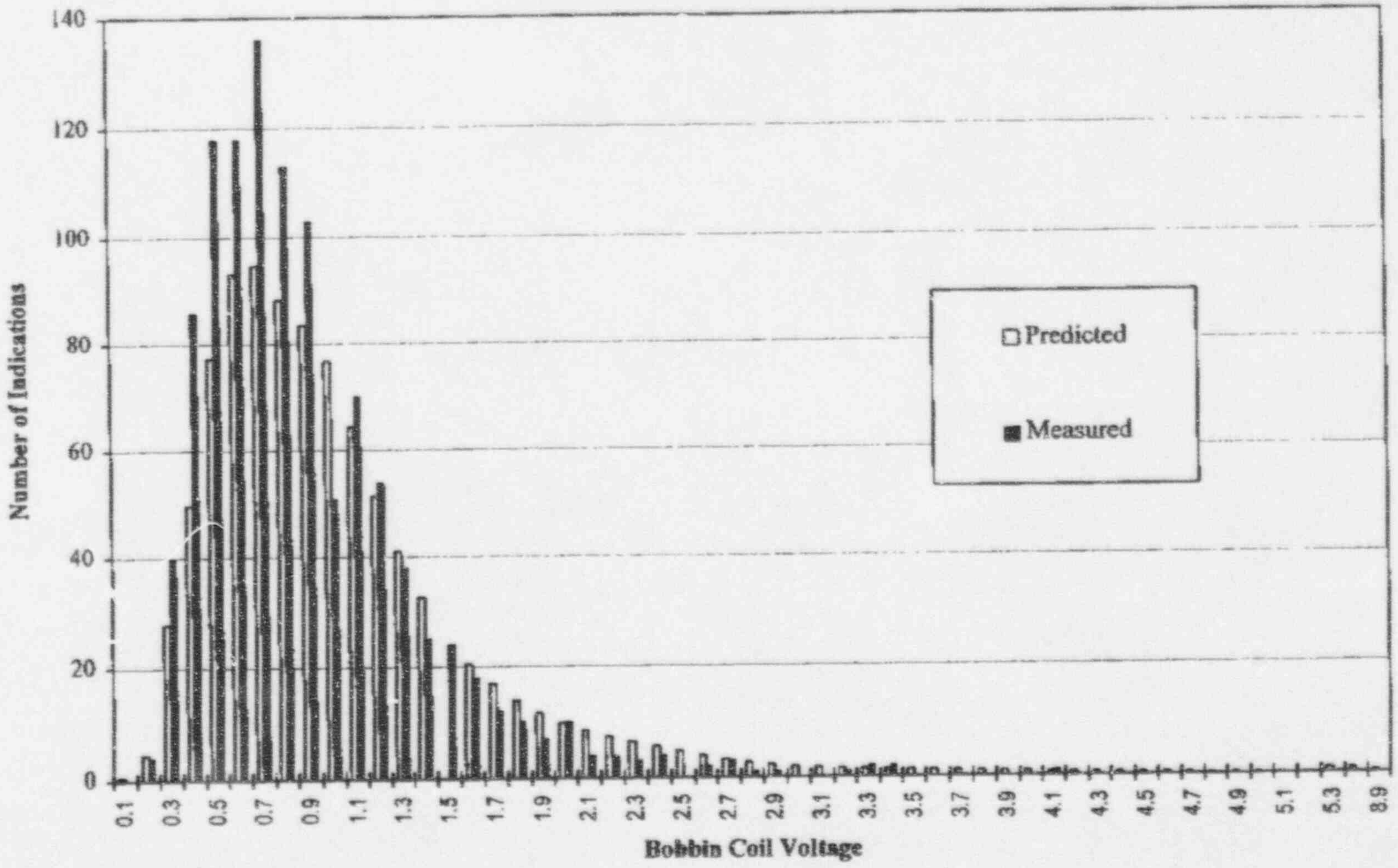

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Figure 6 - 4B

Braidwood Unit - 1

Comparison of Measured and Predicted EOC-5A Voltage Distributions

Steam Generator - B -- POD = 0.6

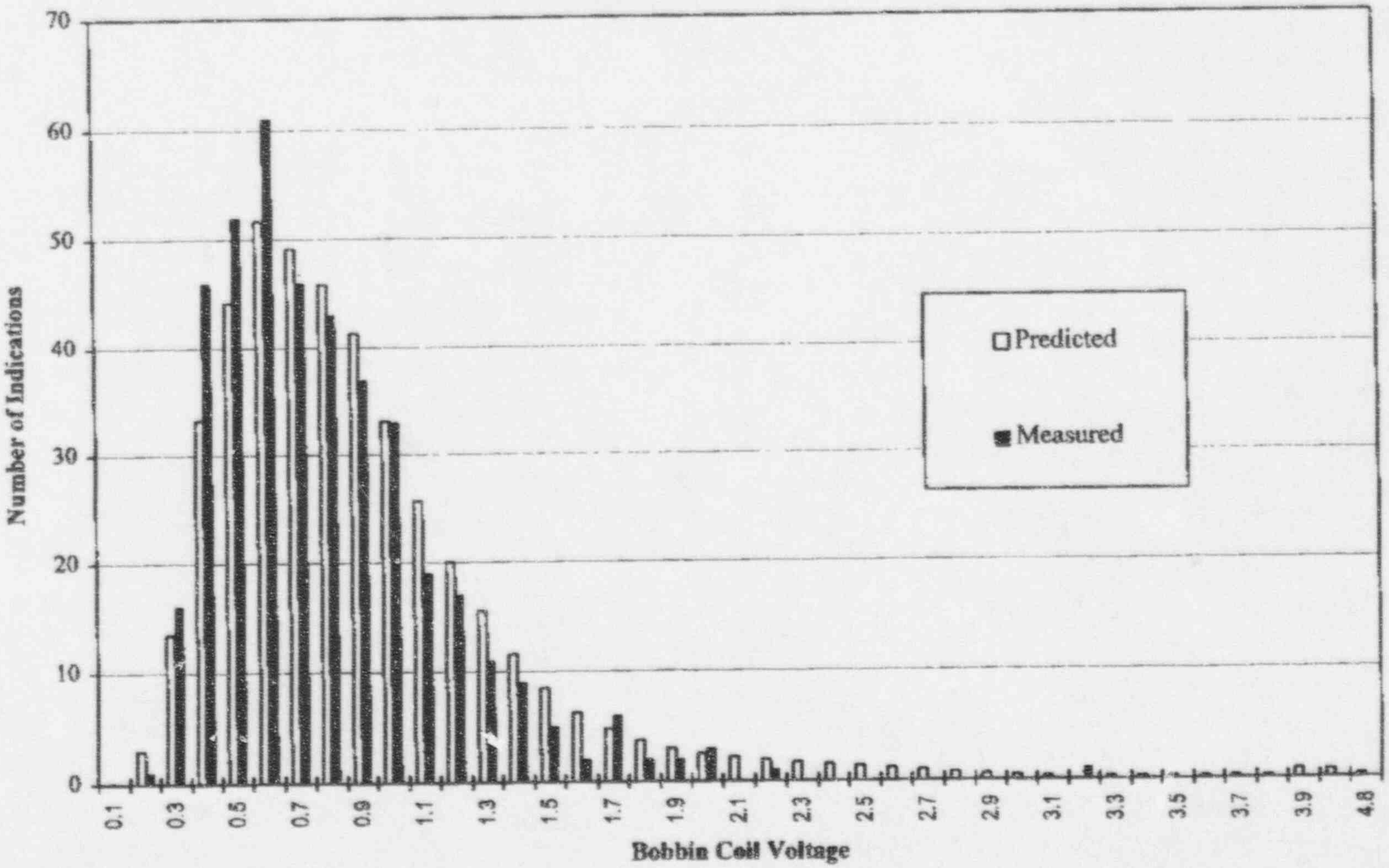

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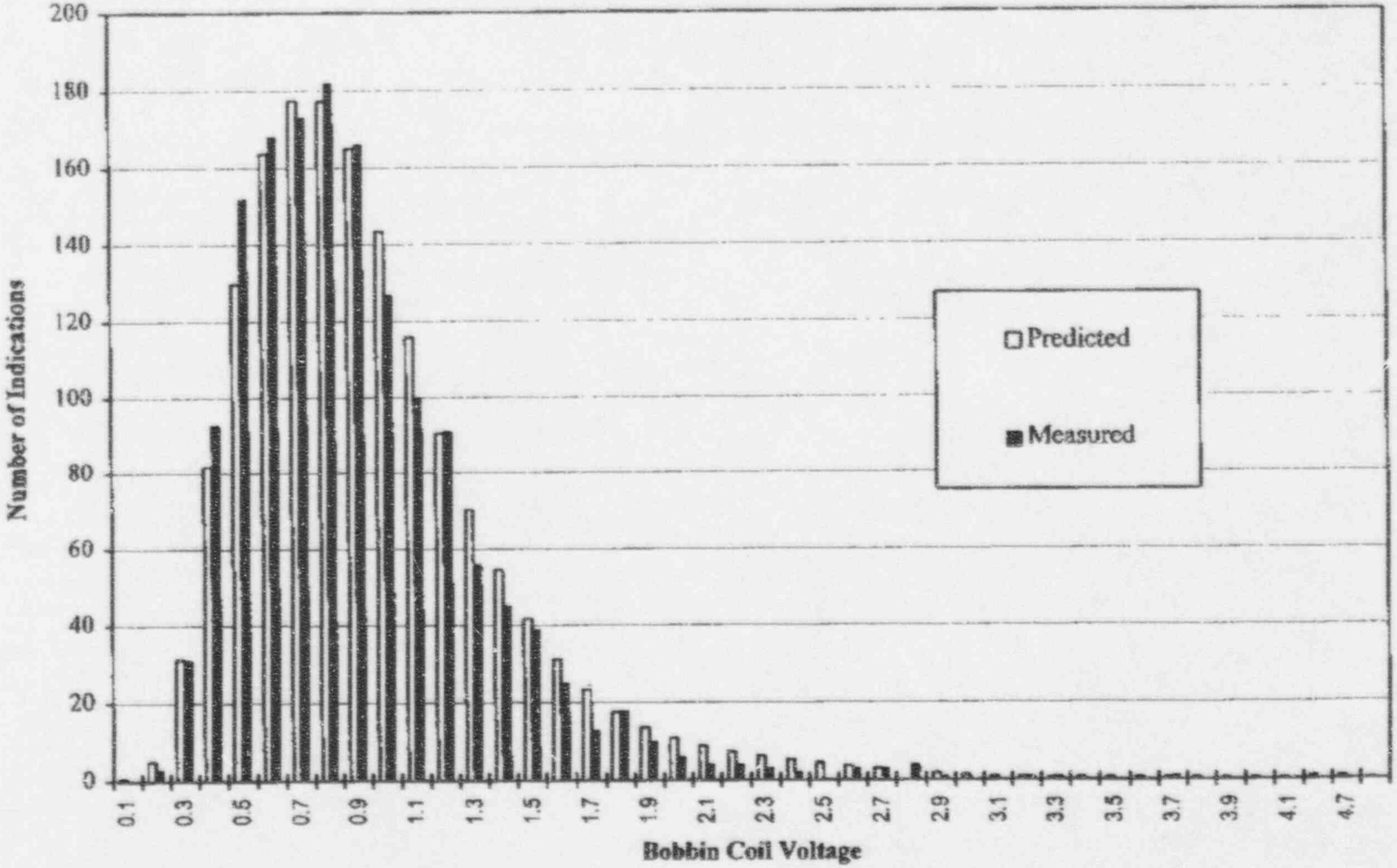
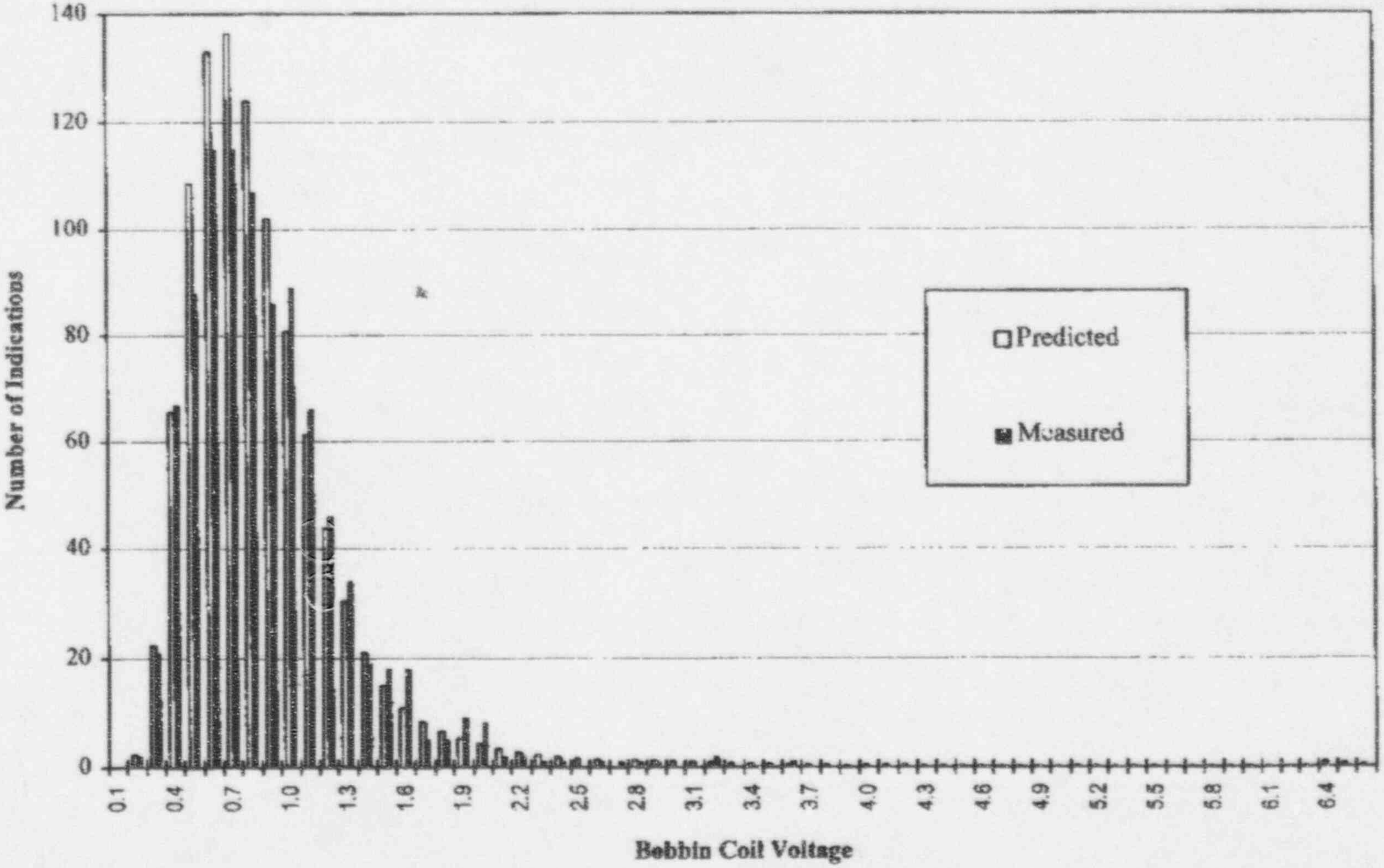
Figure 6 - 4C
Braidwood Unit - 1
Comparison of Measured and Predicted EOC-5A Voltage Distributions
Steam Generator - C -- POD = 0.6



PREDCOMP.XLWFig 6-4C6/6/95 4:08 PM

Figure 6 - 4D
Braidwood Unit - 1
Comparison of Measured and Predicted EOC-5A Voltage Distributions
Steam Generator - D -- POD = 0.6



PREDCOMP XLWFig 6-4D6/8/95 4:08 PM

Figure 6 - 5A
Braidwood Unit - 1
Voltage Distribution Prediction for EOC-5B
Steam Generator - A -- POD = 0.6

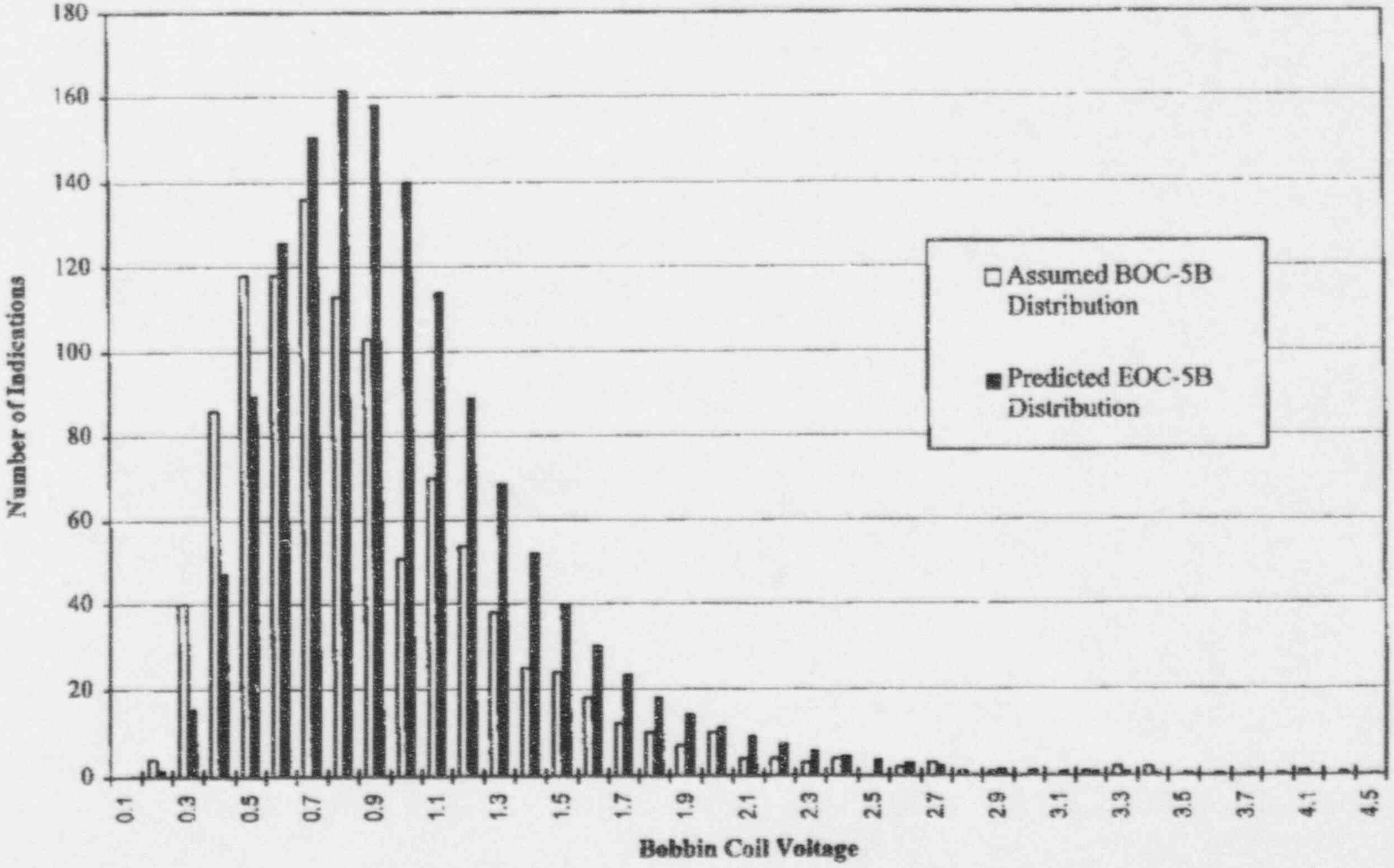
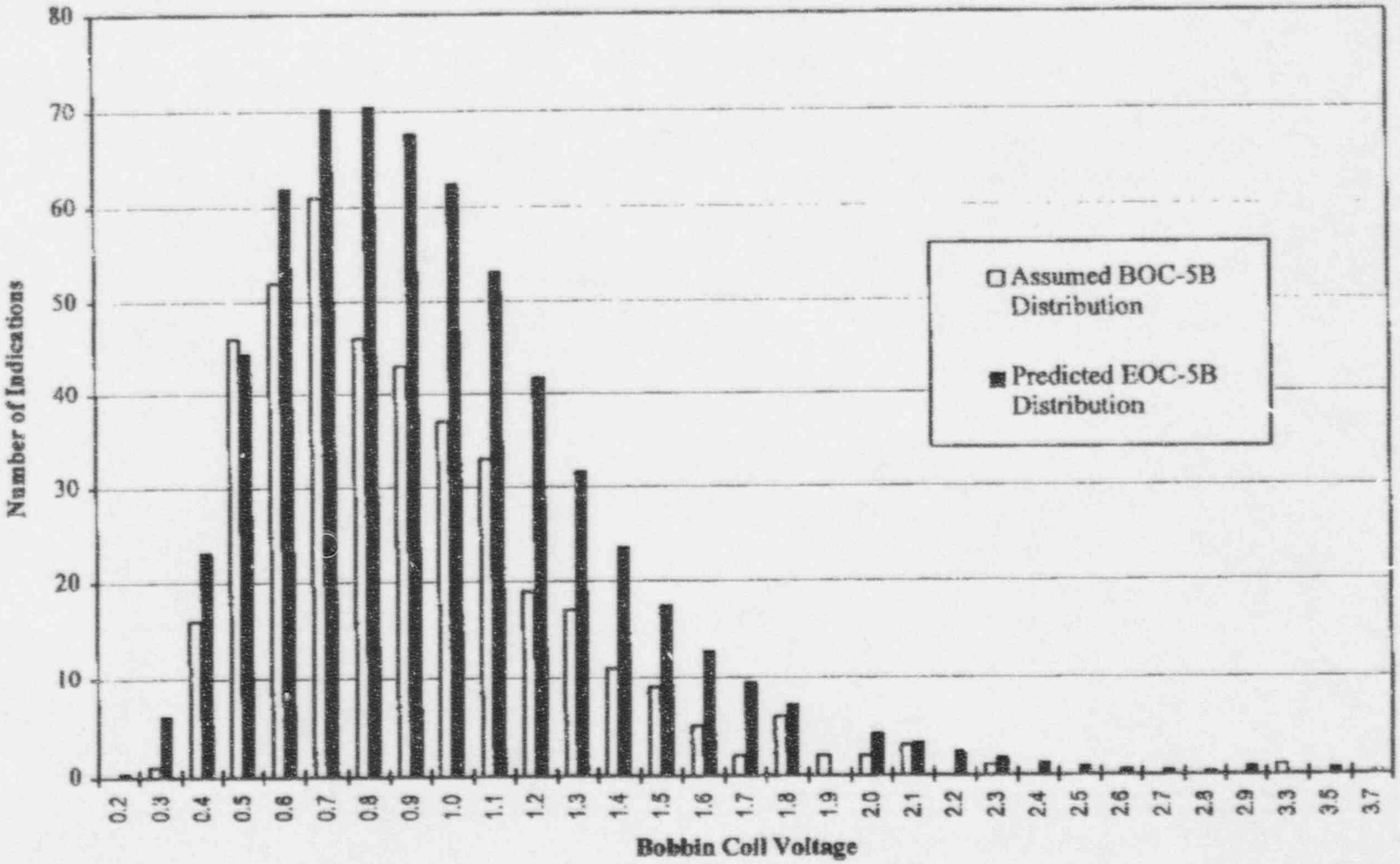


Figure 6 - 5B
Braidwood Unit - 1
Voltage Distribution Prediction for EOC-5B
Steam Generator - B -- POD = 0.6



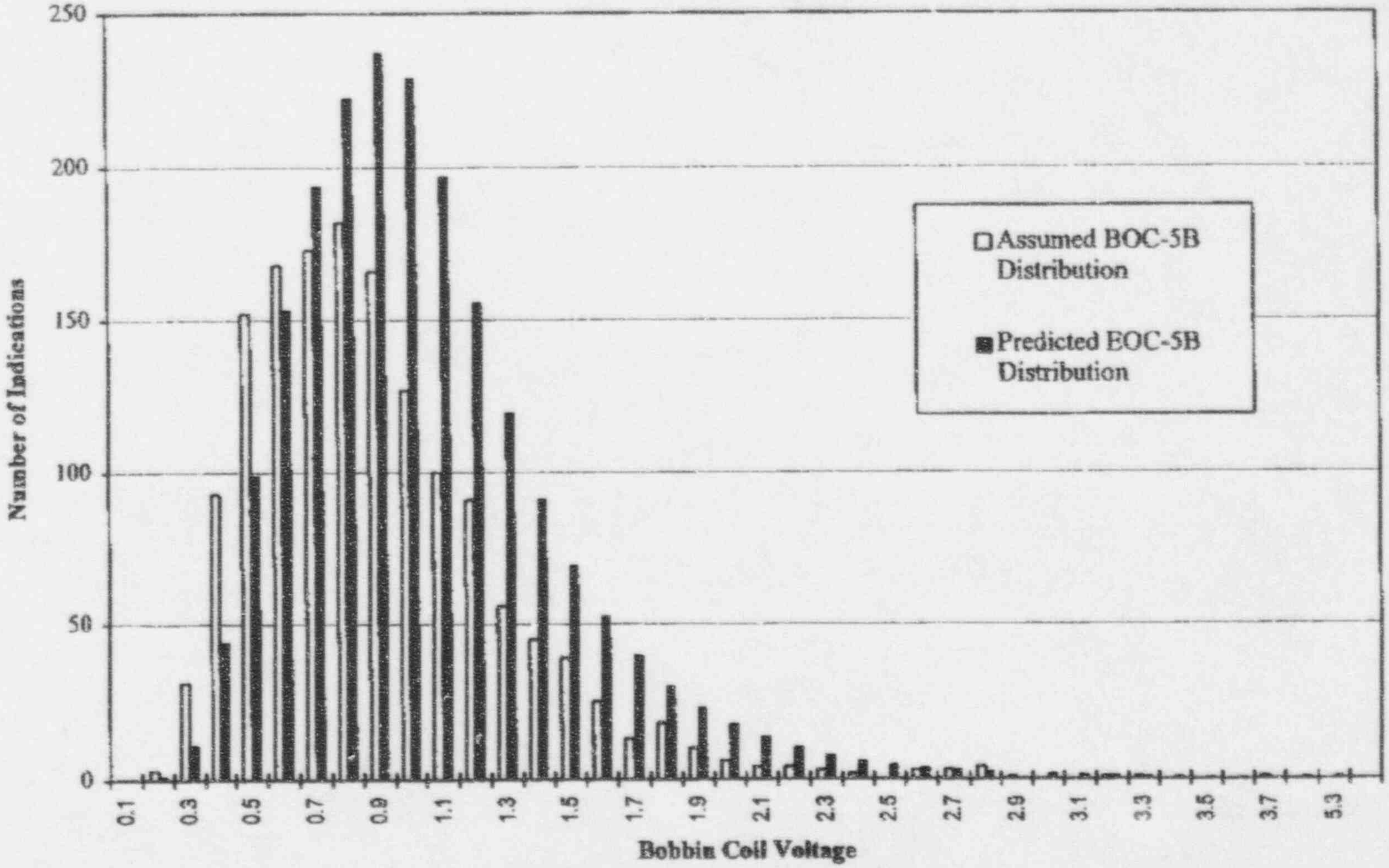
PREDCOMP.XLWFig 6-5B6/6/95 5:05 PM

Figure 6 - 5C

Braidwood Unit - 1

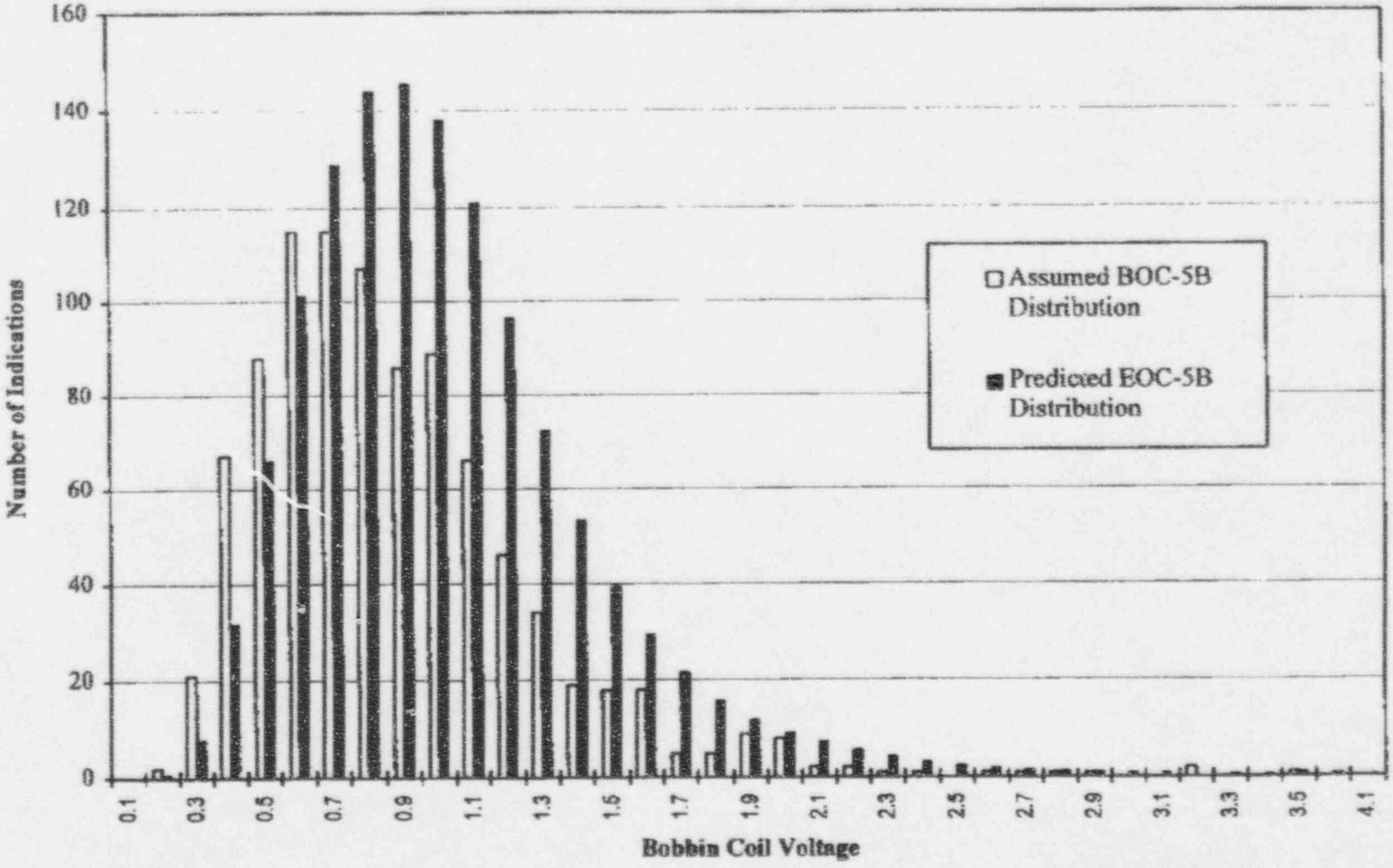
Voltage Distribution Prediction for EOC-5B

Steam Generator - C -- POD = 0.6



PREDCOMP.XLW/Fig 5-5C/6/8/95 6:05 PM

Figure 6 - 5D
Braidwood Unit - 1
Voltage Distribution Prediction for EOC-5B
Steam Generator - D -- POD = 0.6



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7.0 TUBE LEAK RATE AND TUBE BURST PROBABILITIES

7.1 LEAK RATE AND TUBE BURST PROBABILITY FOR EOC-5A

Using the methodology previously described in this report, analyses were performed to calculate EOC-5A SLB leak rate and tube burst probabilities for the actual and predicted bobbin voltage distribution previously presented in this report. The results of Monte Carlo calculations performed for the predicted and the actual voltage distributions, based on the growth distributions of Table 3-6 and the indication population of Table 6-1, are summarized on Table 7-1. Comparison of the EOC-5A actuals with the corresponding predictions indicates that:

a) SG D was predicted to be the most limiting steam generator for EOC-5A, with the highest tube leak and POB numbers.

b) SG C was determined to have the highest tube leak and POB numbers based on actual ECT bobbin measurements for EOC-5A.

c) The leak and POB predictions (based on projected indication population) for all four SGs are conservative compared to actual leak and POB values (based on ECT bobbin measurements for EOC-5A). The projections for SG D are conservative by approximately an order of magnitude.

d) A voltage based POD may conservatively predict tube leak and POB, possibly with greater accuracy than POD = 0.6.

7.2 LEAK RATE AND TUBE BURST PROBABILITY FOR EOC-5B

Calculations have been conducted to predict the performance of the limiting steam generator in Braidwood Unit 1 at EOC-5B conditions. The methodology used in these predictions is the same as previously described for EOC-5A. Results of the EOC-5B predictions are summarized on Table 7-1. With POD = 0.6, the projected EOC-5B SLB leak rate for S/G C is calculated as 0.48 gpm and the EOC-5B SLB tube burst probability is calculated as 4.94 E-03. The performance of the individual steam generators, shown on Table 7-1, indicates that the limiting steam generator for Cycle 5B of Braidwood Unit 1 is expected to be SG C.

Table 7 - 1

Braidwood Unit 1 1995 Midcycle 5 Outage
Summary of Calculations of Tube Leak Rate and Burst Probability Based on Predicted and Actual Bobbin Voltage - 100k Simulations

Steam Generator	POD	No. of Indications	Max. Volts	Burst Probability		SLB Leak Rate gpm
				1 Tube	2 Tubes	
EOC-5A PROJECTIONS						
A	0.6	948.	8.9	1.52 E-02	2.39 E-04	1.44
B	0.6	433.	4.8	1.69 E-03	None	0.21
C	0.6	1597.	4.9	3.45 E-03	None	0.44
D	0.6	1012.	10.9	3.08 E-02	5.96 E-04	2.81
EOC-5A ACTUAL						
A	1.0	1065.	4.3*	2.02 E-03	4.75 E-05	0.22
B	1.0	413.	3.4	3.26 E-04	None	0.03
C	1.0	1526	5.5	3.04 E-03	None	0.32
D	1.0	931.	3.8	1.07 E-03	4.75 E-05	0.12
EOC-5B PREDICTED						
A	0.6	1401.	4.5	2.92 E-03	4.75 E-05	0.33
B	0.6	627.	3.7	7.81 E-04	None	0.08
C	0.6	2051.	5.6	4.94 E-03	4.20 E-05	0.48
D	0.6	1269.	4.1	1.97 E-03	4.20 E-05	0.22

* Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.

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 Draft NRC Generic Letter 94-XX, "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 1994.

Attachment B

Review of Programs Implemented to Reduce SG Tube Degradation

Per a commitment from a letter from NLA (Denise M. Saccomando) to the NRC on November 23, 1994, ComEd is required to assess the indication voltage growth rates by reviewing the effectiveness of the various programs which were put in place or were already in place to mitigate degradation. The various programs which were put in place or were already in place to mitigate degradation include:

Following the EPRI Secondary Chemistry Guidelines
Maintaining Condensate Dissolved Oxygen below 3 ppb
Reduce iron transport to the SG by use of ethanolamine (ETA)
Implement a Secondary Boric Acid Program
Evaluate Hideout Return information
Continue to follow the Molar Ratio Control Program
Installation of a Reverse Osmosis unit in the Make-up Demineralizer (MUD) system
Eddy Current the Main Condenser
Maintain elevated hydrazine concentration in the FW system
Review the need to chemically clean the SG's
Evaluate the use of other amines to reduce iron transport
Evaluate the use of other chemicals to improve iron transport out of the SG

A list of these programs was provided to the NRC in a letter from K. L. Kofron on May 2, 1994. This assessment is required to be performed following the A1M05 outage and within 90 days following the startup from A1M05. Voltage growth rate data is available from Braidwood Unit 1 Cycle 4 and the first part of Cycle 5. Data is also available for the 1C SG at two periods of Cycle 4 due to an eddy current inspection being performed in the middle of the cycle due to a primary to secondary leak in October 1993.

On March 31, 1994, personnel from the station Chemistry Department, Corporate Chemistry Support organization, the Corporate SG and RPV Projects, and SEC met to perform this assessment. The following is a summary of our findings.

EPRI Secondary Chemistry Guidelines

The EPRI guidelines, as incorporated into procedure BwCP PD-4, Braidwood Station Secondary Water Chemistry Surveillance Program, were followed. There are some differences between the EPRI Guidelines and BwCP PD-4. The chemistry programs for Cycle 4 and 5 were no appreciably different, therefore, the issue could not have contributed to the increase in SG tube indication voltage growth rate.

Condensate Dissolved Oxygen

For the most part, Condensate Dissolved Oxygen (CD Dis. O2) is maintained below 3 ppb. Cycle 5 had occasions of high CD Dis. O2 (in the range of 200 ppb) due to the periodic operation of the 1A CD Pump which had a seal leak following A1R04. Every time the 1A CD Pump would be run, the CD Dis. O2 would increase to approximately 200 ppb. The Dis. O2 would return to normal when the 1A CD Pump was shut down. Due to this problem, the 1A CD Pump was not normally run. The pump was repaired in cycle 5. In addition to this, entries were made into the Condenser waterboxes during Cycle 4 and 5 to search and repair Condenser tube leaks. CD Dis. O2 always elevates when a waterbox is taken off-line. System Engineering has reviewed this problem and has determined that it is due to Steam Jet Air Ejector (SJAE) drawing gases from the waterbox with the highest pressure i.e. the waterbox which is off-line. Therefore, the condenser is not removing the non-condensable gases from the waterboxes that are in service causing the CD Dis. O2 to elevate. During Cycle 4, modest elevations in CD Dis. O2 were noted. In Cycle 5, Action Level 2 for CD Dis. O2 (>30 ppb) was typically entered whenever a waterbox was taken off-line. The difference between taking a waterbox off-line during Cycle 4 and Cycle 5 is attributed to differences in the amount of air inleakage during these cycles. During Cycle 4, there was moderate air inleakage (<10 SCFM). During Cycle 5, there was high air inleakage (>15 SCFM). It should be noted that after the repair of the Turbine Rupture Discs during a forced outage of Cycle 5 in May 1995 (after A1M05), the air inleakage after unit startup was reduced to <10 SCFM. When a waterbox was taken off-line following this outage with the reduce air inleakage, Action Level 2 for CD Dis. O2 was not entered. The conclusion drawn from this information was to try to maintain the air inleakage below 10 SCFM so that the station is are prepared to take a waterbox off-line without entering Action Level 2. System Engineering is investigating a modification to isolate the SJAE from drawing gases from a waterbox which is off-line.

Another potential problem with CD Dis. O2 is the performance of the AF Full Flow test. During this test, typically performed just prior to going into a refueling outage, cold, air saturated water (6 to 8 ppm Dis. O2) from the Condensate Storage Tank (CST) is injected into the SG's from the AF Pump for a short time. System Engineering has an open item to review the requirement to perform this test to see if the frequency of the test can be reduced. Some plants (Commanche Peak and Shearon Harris) have installed a nitrogen sparge on their CST's which also functions as a nitrogen blanket. These two features combine to reduce the CST Dis. O2 concentration. Even if the frequency of this surveillance is reduced, cold, air saturated water from the CST is injected into the SG by the AF Pumps during a Reactor trip. The amount of oxygen ingress during a Reactor trip can only be reduced if the Dis. O2 concentration in the CST is reduced, or the frequency of Reactor trips is reduced.

Figure 1 suggests there may be a link between Condensate Dissolved Oxygen and SG tube voltage growth rate. There is insufficient data to draw a strong conclusion, but reducing

the time CD Dis. O2 is in an action level and reducing the concentration of CD Dis. O2 while in the action level could be recommended until further information is available.

Reduce Iron Transport

Iron transport has been reduced by the use of ETA. ETA was started in Cycle 4. The Cycle 5 FW iron concentration is less than the FW iron concentration in Cycle 4 (pre and post ETA implementation). Byron is testing the use of a different amine, 3-methoxypropylamine (MPA). Data from Byron should be available by the middle of 1995. The group decided to continue with the use of ETA and review the data from Byron once it is available. With the reduction in FW iron transport and increase in SG voltage growth rate, it is believed that iron transport did not contribute to the increased voltage growth rate.

Implementation of a Secondary Boric Acid Program

The Secondary Boric Acid Program began at the startup from the A1R04 outage. The program consists of a low power Boric Acid soak along with maintaining a residual boric acid concentration at high power. No reduction of the initiation of new cracks in the SG tubing was noted. No reduction in the voltage growth rate of existing cracks in the SG tubing was noted. A high concentration boric acid soak at low power (200 ppm at <15% power) was performed during the startup from the A1M05 outage. A low concentration soak at low power (50 ppm at <30% power) was performed during a startup from a forced outage after A1M05. A review of the Boric Acid program with input from Westinghouse is planned. The group decided to continue the Secondary Boric Acid Program through Cycle 5 including the performance of low power boric acid soaks. A review of the results from the A1R05 eddy current inspection will be performed to determine if the program should be continued for Cycle 6.

Hideout Return

Review of the hideout return data from Cycle 5 shows that the sodium to chloride molar ratio is above 1 and that there appears to be more sodium return from shutdowns that occurred after the implementation of the Secondary Boric Acid Program as compared to the amount of sodium that returned prior to the programs implementation. A Secondary Boric Acid program is believed to impact the sodium hideout. There was no Boric Acid hideout return. The hideout return sodium to chloride molar ratio was higher than past shutdowns. Since the implementation of the Molar Ratio program, the crevice pH, based on the hideout return data and calculated from the EPRI MULTEQ program, has been reduced to what is believed an acceptable range. With no boric acid hideout return, boric acid did not contribute to the reduction in crevice pH. Even if there had been boric acid hideout return, it would not play a major role in reducing SG crevice pH.

Molar Ratio Program

The group decided that the molar ratio program has had a positive effect on the SG crevice pH although this effect has not reduce the SG tube degradation. Since the program has negligible costs, the group decided to continue the program. The molar ratio program and its effects on SG degradation was reviewed by an independent contractor (Dominion Engineering, Inc.) as part of an EPRI study. The preliminary conclusion is that Molar Ratio Control (MRC) "per the MRC guidelines, in conjunction with ALARA impurity control, high hydrazine, and boric acid, appears to be worth trying, but cannot be relied upon to stop IGA/SCC." Comparing the average cycle molar ratio to the average SG tube voltage growth per EFPY (see Figure 2) no correlation could be drawn between the molar ratio and the SG tube indication voltage growth rate.

Questions have been raised in the past concerning the effects of chloride on SG tubing. At the low concentration of chloride used for the Molar Ratio Program, there is negligible effect of chloride on the SG tubing.

Installation of a Reverse Osmosis Unit in the MUD System

The installation of the Reverse Osmosis Unit in the MUD system (November 1992) was evaluated to be successful in improving the operation and performance of the MUD system although its effect in mitigating the degradation of the SG tubing is believed to be negligible. The group decided to continue the operation of the Reverse Osmosis unit due to it improving the operation and performance of the MUD system and due to its cost benefits for the MUD system.

Condenser Eddy Current Program

Two waterboxes (1C and 1D) were eddy current tested during A1R03. One waterbox (1A) along with 15% of the fourth waterbox (1B) was eddy currented tested during A1R04. The remainder of the fourth waterbox will be eddy current tested during the A1R05 outage. Several hundred tubes have been plugged as a result of the eddy current program, but Condenser tube leaks have occurred in tubes that were eddy current tested. The recent Condenser tube leaks have mainly been from tubes on the outside row of the tube bundle and have occurred in the Winter months. It is believe that the cold CW in the Winter months is causing wear of the Condenser tubes due to steam impingement. Some outside row tubes have been preventatively plugged. More outside row tubes are planned to be preventatively plugged prior to the A1R05 outage. Eddy current testing of the 1B waterbox and preventative plugging of outside row tubes in all waterboxes will reduce the leakage from these tubes. This reduction in leakage is consistent with the industry recommended ALARA chemistry program.

Maintain Elevated Hydrazine Concentration in the FW System

Elevated hydrazine (>100 ppb in FW) has been maintained in Cycle 4 and 5. There was no noticeable changes in the elevated hydrazine program between Cycle 4 and 5, therefore, it is not believed that elevated hydrazine contributed to the increase in voltage growth rates from Cycle 4 to 5. The group decided to continue elevated hydrazine operation due to its potential to reduce SG tube degradation and its effort in reducing erosion/corrosion of the CD system.

Review the Need to Chemically Clean the SG's

With the decision to replace the SG's in A1R07 (1998), there is little opportunity for SG chemical cleaning to be beneficial. Braidwood will review the SG eddy current results from Byron's mid-cycle outage (B1P02) to complete the review of the benefits of SG chemical cleaning.

Evaluate the Use of Other Amines to Reduce Iron Transport

As mentioned above, the use of MPA at Byron is being reviewed for Braidwood. Presently, MPA is the only other amine under evaluation. The performance SG soaks with dimethylamine (DMA) is also being evaluated. Since the use of amines other than ETA was not incorporated in Cycle 4 or 5, they could not have contributed to the increase in voltage growth rate.

Evaluate the Use of Other Chemicals to Improve Iron Transport Out of the SG

Discussions are in progress with chemical manufactures to develop a polymer that will disperse iron to improve removal by the SG blowdown system. The contract for testing the should be issued soon. Testing of the polymer in a ComEd SG is planned for later this year. Since the use of polymers was not incorporated in Cycle 4 or 5, they could not have contributed to the increase in voltage growth rate.

In addition to the above listed issues for discussion, two other issues were discussed as possible future programs.

SG Blowdown Flow Reduction

The group decided they wanted to review what the effect of reducing SG Blowdown flow would have on the hideout molar ratio. Reducing SG Blowdown flow will lengthen the life of the SG Blowdown resin and, therefore, reduce the sodium ingress or improve the sodium removal efficiency. At the same time, the concentration of the anions, excluding the effects of the Molar Ratio Control Program, should increase in the SG. Periods of reduced SG blowdown flow have occurred in the past. The reduction in flow did not increase the impurities in the SG appreciably during periods of low chemical ingress.

During periods of higher amounts of chemical ingress, some elevation of impurities was observed. These elevations are typically less than 2 ppb, therefore not jeopardizing any action levels.

Secondary Lay-up

Lay-up practices of the secondary systems (CD, FW) in the past has only been to drain the systems and leave the drains open. The systems have not been dried with air or inerted with nitrogen. Due to this, the systems can contain a high moisture atmosphere. This leads to elevated corrosion of the systems. The group felt that better lay-up practices should be implemented. The group agreed to start with the lay-up of the Main Condenser. Dehumidifiers are being evaluated for use during A1R05. The use of dehumidifiers at other plants has proven to be beneficial in reducing the iron transport during unit startup. Iron transport during unit startup is believed to be a major contributor to the total iron transport to the SG's.

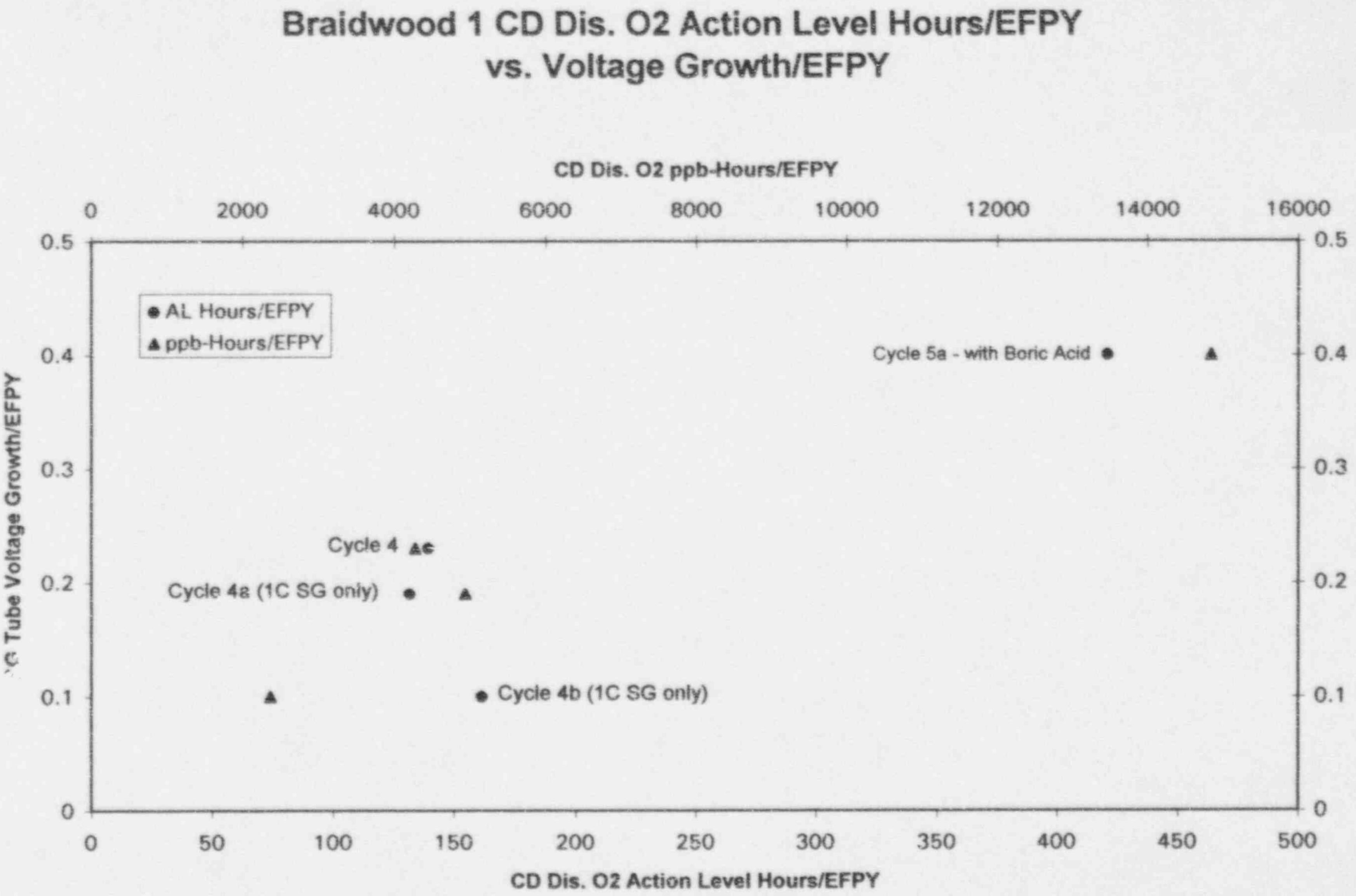
Conclusion

This completes the review of the effectiveness of the various programs which were put in place or were already in place to mitigate degradation. No strong conclusions could be identified that relate secondary chemistry operation to changes in SG indication voltage growth rates although the following goals were set:

1. Reduce the occurrence, duration, and the concentration above Condensate Dissolved Oxygen action level;
2. Ensure the 1B waterbox is eddy current tested and the necessary outside row tubes in all waterboxes are preventatively plugged;
3. Evaluate the effect of reduced SG Blowdown flow in an attempt to alter the chemical environment in the SG's; and
4. Evaluate the use of dehumidifiers in the Main Condenser during A1R05.

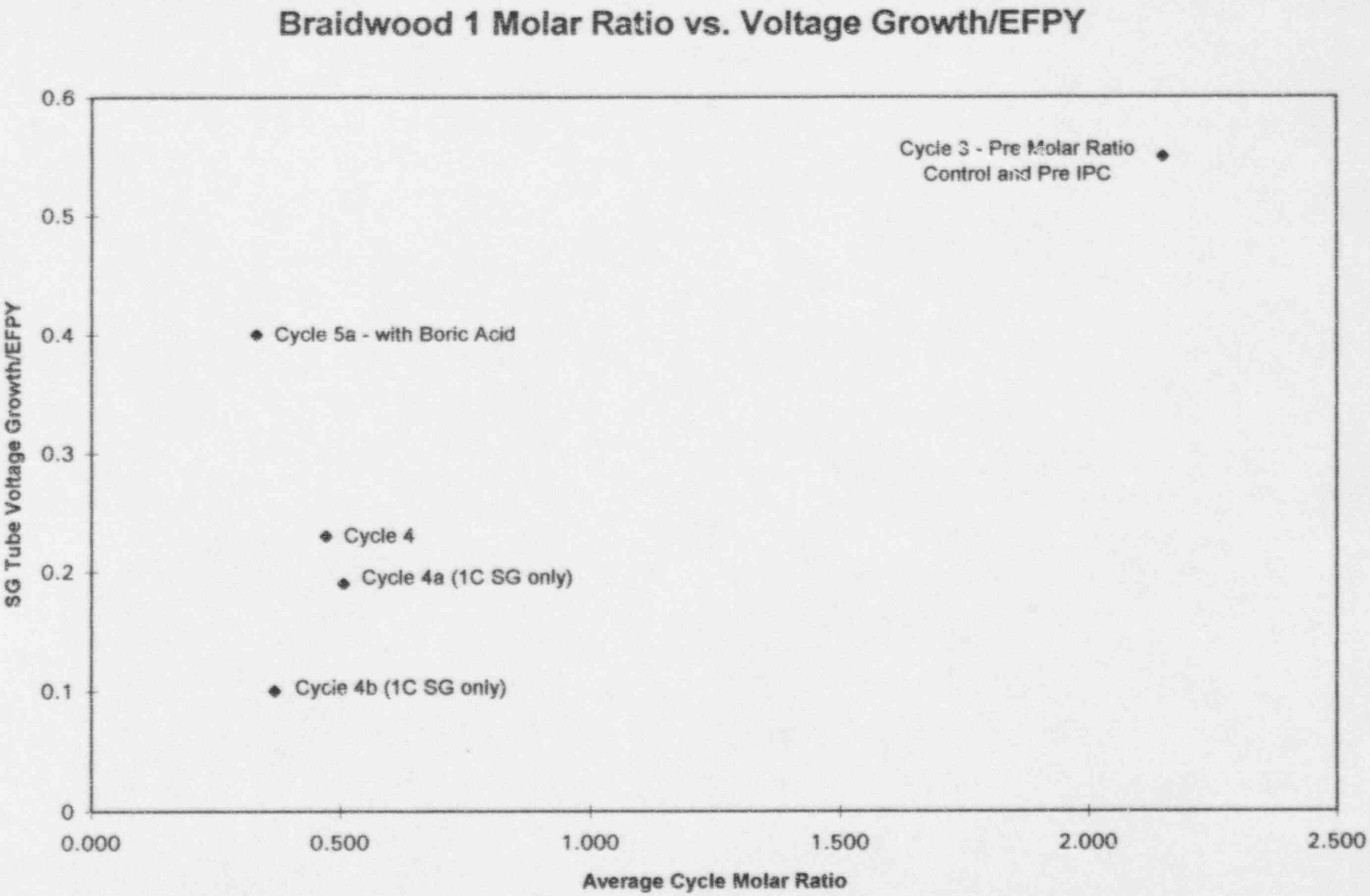
The secondary chemistry program is evaluated following each refuel outage as required by BwCP PD-4. A review of these programs is included in this evaluation.

Figure 1



Braidwood 1 CD Dis. O2 Action Level Hours/EFPY
vs. Voltage Growth/EFPY
CD Dis. O2 ppb-Hours/EFPY
0
2000
4000
6000
8000
10000
12000
14000
16000
0.5
0.4
0.3
0.2
0.1
0
● AL Hours/EFPY
▲ ppb-Hours/EFPY
Cycle 5a - with Boric Acid
Cycle 4
Cycle 4a (1C SG only)
Cycle 4b (1C SG only)
SG Tube Voltage Growth/EFPY
0
50
100
150
200
250
300
350
400
450
500
CD Dis. O2 Action Level Hours/EFPY

Figure 2


Braidwood 1 Molar Ratio vs. Voltage Growth/EFPY
SG Tube Voltage Growth/EFPY
Average Cycle Molar Ratio
0.6
0.5
0.4
0.3
0.2
0.1
0
0.000
0.500
1.000
1.500
2.000
2.500
Cycle 3 - Pre Molar Ratio Control and Pre IPC
Cycle 5a - with Boric Acid
Cycle 4
Cycle 4a (1C SG only)
Cycle 4b (1C SG only)