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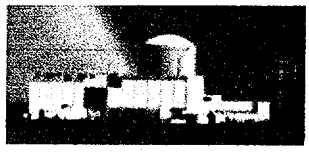

August 23, 2000

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Ladies/Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Kewaunee End Of Cycle 23 Steam Generator Alternate Repair Criteria 90 Day Report

Enclosed please find the "Kewaunee 90 Day Report for Voltage Based Repair Criteria (April 2000 Outage)". This report is being submitted within 90 days of plant startup in accordance with NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking." Monte Carlo codes used to provide the burst and leak rate analysis simulations are based on the methods in WCAP-14277, Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections."

The projected end-of-cycle 24 (EOC 24) SLB tube leak rate and conditional burst probability are well within the regulatory requirements for application of the voltage based repair criteria. Using the NRC probability of detection of 0.6, the EOC 24 tube leakage under SLB conditions (for the limiting steam generator) is projected to be 1.92 gpm, and the probability of burst is projected to be 7.0×10^{-5}. These results meet the Kewaunee site allowable tube leak rate limit of 3.69 gpm and the NRC guideline of 1.0×10^{-2} for tube burst probability.

Please contact Mr. Tim Olson of my staff at (920) 388-8443 if you have any questions or require additional information.

Sincerely,

Kenneth H. Weinhauer
General Manager-Kewaunee

A001

TPO
Enc.
cc - US NRC Region III
US NRC Senior Resident Inspector

FRAMATOME TECHNOLOGIES

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PURPOSE AND SUMMARY OF RESULTS:

During the End-of-Cycle-23 eddy current examinations, an Alternate Repair Criteria (ARC) was implemented in order to allow certain support plate signals to remain in service. The ARC was implemented in accordance with NRC Generic Letter 95-05. Information required by the Generic Letter is documented in this report including bobbin voltage distributions, and results of leak rate and probability of burst calculations.

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THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

Record of Revision

Rev. Number	Change Section/Paragraph	Description of Change
00		Initial Release
01	Section 1.2	Misc. Editorial Changes
	Sections 1.2 and 5.1	Corrected Allowable Leak Rate
	Section 2.1	Corrected Mixed Residual Inspection Criterion
	Section 3.2	Removed Table 3-1
	Section 5.1	Corrected POB Value in Text of Section
	Section 6.0	Corrected Ref. 6.12

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1.0 Introduction

The Kewaunee Nuclear Power Plant (KNPP) began commercial operations in June 1974 and in April 2000 had completed Cycle 23. The plant employs two Westinghouse Model 51-steam generators with $^{7}/_{8}$-inch OD inconel-600 tubing. The tube support plate (TSP) design is ¾-inch thick carbon steel plate with drilled holes.

Outside Diameter Stress Corrosion Cracking (ODSCC) has been confirmed within the TSP regions of both Kewaunee steam generators. NRC Generic Letter 95-05 (Reference 6.1), outlines an approved plan for allowing tubes containing ODSCC indications to remain in service if the indications are totally contained within the TSP and the measured bobbin voltage is ≤2.0 volts (for steam generators with $^{7}/_{8}$-inch tubing). The complete list of exclusion of intersections is provided in section 1.b of Reference 6.1. The NRC has approved implementation of the voltage based repair criteria at Kewaunee per Reference 6.2. The End of Cycle (EOC) 23 inspection was the fourth implementation of the voltage-based alternate repair criteria (ARC) defined in Reference 6.1.

In accordance with the NRC Generic Letter 95-05, ARC implementation requires a post eddy current inspection tube integrity assessment. The assessment must include calculated conditional probability of burst and calculated leak rate during a postulated MSLB on the last day of the upcoming operating cycle. Framatome Technologies, Inc. (FTI) uses Monte Carlo codes, as described in References 6.8 and 6.9, to provide the burst and leak rate analysis simulations. FTI's Monte Carlo codes are based on methods in Reference 6.7. The analysis inputs include beginning of cycle (BOC) bobbin voltage distributions adjusted with the NRC-approved probability of detection, repaired tubes, tubes returned to service, measurement uncertainties, and voltage growth rate distributions. The analysis projects EOC bobbin voltage distributions and calculations for probability of burst and leak rate. The correlation parameters are obtained from EPRI's ODSCC ARC Database (Ref. 6.3) as described in Section 1.3.

1.1 Inspection Summary

The April 2000 eddy current inspection, following Cycle 23, at Kewaunee, revealed a total of 1203 Distorted Support Signals (DSS) that were candidates for the ARC prior to deplugging. There were no indications detected that exceeded the upper repair limit of 5.33 volts. There were an additional 63 DSS indications that were returned to service by deplugging. The voltage range of detected DSS indications that were in service during Cycle 23 extended from a low of 0.11 volts to a high of 3.42 volts in SG A and 0.11 volts to 2.85 volts in SG B.

The average growth rate for both steam generators combined was 3.2% per EFPY. This growth rate represents the voltage growth for Cycle 23 as

compared to the BOC-23 voltage and is well below the 30% per EFPY criteria specified in NRC Generic Letter 95-05. In addition, the measured growth rates calculated for Cycle 23 were comparable to previous cycles (2.2% per EFPY for Cycle 22 and 3.9% per EFPY for Cycle 21); refer to Table 2-3 for additional details.

Some plants have seen accelerated growth rates for DSS's in tubes which have recently been returned to service. Therefore, growth rates for deplugged tubes and tubes which have been continuously in service were determined separately. These separate growth distributions were then combined based on the number of DSS's in each category being returned to service for Cycle 24. Section 3.5 provides more detailed information on the growth rate distributions.

1.2 Conclusions

The requirements for burst probability were met based on the projected population of indications at EOC-24. Neither steam generator exceeded the 1×10^{-2} criteria. For both steam generators, the postulated leak rate at EOC-24 was also within the available limit of 2.69 gpm. Note that the total allowable leak rate of 3.69 gpm is reduced by 1 gpm to account for the large population of HEJ sleeves that are in service at KNPP. Table 1-1 provides a summary of the EOC-24 calculations based on an expected cycle length of 1.22 EFPY.

Table 1-1
Burst Probability and Tube Leak Rate Results at EOC-24
Using an Expected EFPY of 1.22

SG	PROBABILTY OF BURST 95%UCL / 1 OR MORE FAILURES	SLB[1] LEAK RATE (GPM)
A	$3.4\text{x}10^{-5}$	0.61
B	$7.0\text{x}10^{-5}$	1.92

1: SLB refers to Steam Line Break (see Section 4.3)

Additional details of these results may be found in Section 5.0. The requirements of NRC Generic Letter 95-05 are satisfied for plant operation until EOC-24.

1.3 EPRI ARC Database

Addendum 3 to EPRI report NP-7480-L (Reference 6.3) was released in 1999 and extends the database for ODSCC at TSPs by adding pulled tube data from 4 plants with 7/8 inch tubing. The ARC correlations for burst pressure and probability of leakage which were used for the EOC-24 projections were obtained from Reference 6.3. Since none of the new pulled tube tests resulted in any leakage, the leak rate correlation is unchanged from the Addendum 2 update and was not included in the Addendum 3 update. Therefore, the parameters for the leak rate correlation were taken from the 1998 Addendum 2 update (Ref. 6.11). These correlations between bobbin voltage and burst pressure, leak rate, and probability of leakage are shown below.

$$BurstPressure(ksi) = \boldsymbol{P_B} = 8.261536 - 2.61495*\log(Volts) \qquad \text{Eq. 1-1}$$

$$LeakRate(l/hr) = \boldsymbol{Q} = 10^{[-0.526882 - 0.987179*\log(Volts)]} \qquad \text{Eq. 1-2}$$

$$ProbabilityofLeakage = \boldsymbol{Pr(Leak)} = \left[1 + e^{[4.31236 - 4.21125*\log(Volts)]}\right]^{-1} \qquad \text{Eq. 1-3}$$

2.0 EOC-23 Inspection Results

2.1 Summary of Results

During the outage following EOC-23 at KNPP, a 100% full-length bobbin coil inspection was performed on all in-service tubes in both steam generators. In addition, a number of tubes in both steam generators were deplugged and inspected full length with bobbin. An augmented inspection was also performed using Plus Point probes. The eddy current inspections performed were consistent with NRC requirements.

The bobbin coil inspection resulted in a total of 1203 Distorted Support Signals (DSS's) from tubes in service during Cycle 23. There were a total of 63 DSS calls from tubes that were deplugged and returned to service for Cycle 24. These indications were distributed between the two steam generators as shown in Table 2-1.

Table 2-1
Summary of EOC-23 As Found Results

	SG-A	SG-B	BOTH
Number of DSS's (new & repeat)	341	862	1203
DSS's 2.01 – 5.33 Volts	1	1	2
DSS's > 5.33 Volts	0	0	0
DSS's Deplugged & Ret. To Service	9	54	63

By comparing as found indications to the projected EOC-23, the use of the 0.6 POD (Probability of Detection) produces conservative results with respect to the quantity of indications actually detected. Table 2-2 shows the actual and previously projected indications. The projected values were obtained from the Cycle 23 90 Day Report (Ref. 6.12).

Table 2-2
EOC-23 DSS Calls, Actual and Projected Indications
(Projected indication distributions were obtained from Cycle 23 90 Day Report)

	Steam Generator A			Steam Generator B	
Voltage Bin	Actual EOC-23	Projected With POD=0.6	Voltage Bin	Actual EOC-23	Projected With POD=0.6
0.1	0	2.10	0.1	0	1.98
0.2	24	46.39	0.2	31	51.19
0.3	54	91.74	0.3	109	162.75
0.4	55	89.69	0.4	121	211.67
0.5	51	66.78	0.5	146	204.69
0.6	46	60.76	0.6	129	172.21
0.7	27	44.13	0.7	77	127.06
0.8	27	29.98	0.8	65	97.59
0.9	15	20.69	0.9	49	72.42
1.0	11	14.47	1.0	32	54.53
1.1	4	10.65	1.1	27	42.13
1.2	5	8.37	1.2	22	31.92
1.3	6	6.93	1.3	16	23.47
1.4	3	5.66	1.4	10	16.94
1.5	1	4.39	1.5	8	12.11
1.6	4	3.25	1.6	4	8.52
1.7	3	2.34	1.7	10	5.79
1.8	3	1.61	1.8	2	3.75
1.9	1	1.04	1.9	3	2.28
2.0	0	0.630	2.0	0	1.30
2.1	0	0.353	2.1	0	0.695
2.2	0	0.185	2.2	0	0.354
2.3	0	0.093	2.3	0	0.172
2.4	0	0.045	2.4	0	0.081
2.5	0	0.020	2.5	0	0.037
2.6	0	0.009	2.6	0	0.017
2.7	0	0.004	2.7	0	0.007
2.8	0	0.002	2.8	0	0.003
2.9	0	0.001	2.9	1	0.002
3.0	0	0.000	3.0	0	0.001
3.1	0	0.000	3.1	0	0.000
3.2	0	0.000	3.2	0	0.000
3.3	0	0.000	3.3	0	0.000
3.4	0	0.000	3.4	0	0.000
3.5	1	0.000	3.5	0	0.000
3.6	0	0.000	3.6	0	0.000
Total	341	512.32	Total	862	1305.68
>1 Volt	31	45.59	>1 Volt	103	149.58
>2 Volt	1	[illegible]	>2 Volt	1	0.006

An upper voltage repair limit was calculated prior to the eddy current inspection. This is the voltage value, above which, DSS indications no longer qualify for the ARC and must be repaired regardless of the Plus Point inspection results. This calculation was performed in accordance with NRC Generic Letter 95-05 and was determined to be 5.33 Volts. The subsequent eddy current examination, as shown in Table 2-1, resulted in no DSS's that measured >5.33 volts from tubes that were in service during Cycle 23. Although not shown in the table, all of the DSS's in the deplugged tubes were also below the 5.33 volt upper repair limit. Equation 2-1 was used to calculate the upper (voltage) repair limit. An estimated cycle length of 1.22 EFPY was used for this calculation.

$$V_{URL} = V_{SL} \div \left[1 + (\%V_{NDE}/100) + (\%V_{CG}/100)\right] \qquad \text{Eq. 2-1}$$

V_{URL} = voltage limit for tube repair
V_{SL} = voltage structural limit from burst pressure and bobbin voltage correlation (8.34 for the current database)
V_{NDE} = NDE voltage measurement error (20%)
V_{CG} = voltage growth anticipated between inspections (30%/EFPY)

Per Reference 6.1, the locations of certain bobbin signals must be inspected with a rotating technique. The following outlines the required rotating coil examinations:

- 100% of DSS indications exceeding 2.0 Volts (bobbin)
- All intersections with interference signals from copper deposits
- All intersections with dent signals exceeding 5.0 Volts (bobbin)
- Mixed residuals that could cause a 1.0 Volt bobbin signal to be misread

During the April 2000 outage at KNPP, the eddy current examination revealed two DSS indications >2.0 Volts. There were no intersections identified as containing copper deposits. However, there were approximately 130 dent signals at TSP locations that had a measured bobbin voltage greater than 5.00 Volts. The vast majority of these were located at the 7th TSP. All of these intersections were examined with Plus Point with no defects found. The case where mixed residual signals may mask a bobbin signal was addressed by performing a Plus Point examination on the SPR (Support Plate Residual) signals >=4.28 volts.

Again, no flaws were detected that were not also detected by the bobbin coil inspection.

2.2 Measured Voltage Growth Rates

The voltage growth analysis of DSS indications detected during the April 2000 eddy current examination was accomplished by comparing EOC-22 data to the EOC-23 data for the same intersections. For new DSS calls, look-ups were performed and where possible, voltages were assigned in the EOC-22 data. These intersections were included in the growth study, in accordance with NRC Generic Letter 95-05. There were 95 new DSS calls made during the EOC-23 examination (33 in SG A and 62 in SG B).

Due to the measurement uncertainties in the eddy current process, some voltage growth comparisons are bound to yield measured decreases in voltage. The NRC Generic Letter 95-05 addresses this and only allows negative growth data points to be included as part of the average growth rate when calculating the upper voltage repair limit. Growth distributions, used to project EOC-24 voltage distributions, cannot use negative growth rate data. Instead the negative growth rates are conservatively re-assigned to zero.

The average voltage growth rate is calculated by comparing the EOC-22 as found results to the EOC-23 as found results, and then correcting for the Cycle 23 operating interval. Each growth value was divided by the Cycle 23 operating interval of 1.3375 EFPY so that the resulting values are in terms of delta volts per EFPY. The average growth value (per EFPY) was then divided by the average BOC-23 voltage to obtain the average percent growth per EFPY. The average growth for both steam generators combined was 3.0% per EFPY which is well below the 30% per EFPY discussed in the NRC Generic Letter 95-05. This data, along with average growth rates from previous inspections, is summarized in Table 2-3.

Kewaunee is currently scheduled to replace steam generators during the next refueling outage. Therefore, calculation of an upper voltage repair limit should not be necessary. However, if determination of an upper repair limit is necessary to support a forced outage, the more conservative 30% per EFPY value should be used.

Table 3-5 shows the measured growth rate distributions for Cycles 22 and 23. As shown in the table, the growth distribution for Cycle 23 is similar to the growth distribution from Cycle 22.

Table 3-6 shows the DSS indications whose measured growth was 0.40 volts or larger for Cycle 23. None of these indications were newly detected indications. There appears to be no preference to steam

generator, elevation, or Plus Point confirmation. However, for the tubes which were deplugged at BOC-23, there does seem to be a slight bias toward larger growth. About nine percent (6 of 69) of the indications which were deplugged and returned to service during the 1998 EOC-22 inspection showed growth values of >=0.40 volts. Only about two percent (23 of 1129) of the remaining indications showed growth values of >=0.40 volts.

Table 3-7 shows the quantity of indications at each Tube Support Plate (TSP) for steam generators A and B (individually) and the composite of A and B. In addition, the maximum and average voltage and growth values for each TSP are shown. Average voltage is the highest at the 1H intersections in both steam generators. The composite section of Table 3-7 shows that the highest concentration of indications are at the 6C, 2C, 7C, 1C, and 1H intersections, in this order. This is typical behavior for the KNPP steam generators.

Figure 3-9 is a scatter plot of BOC-23 voltage versus voltage growth during Cycle 23. The purpose of this figure is to show if there is a relationship between the beginning-of-cycle voltages and the growth rates. The main concern is for the possibility that the larger indications may show larger growth rates. As shown in the chart, there is no apparent relationship between the measured growth rates and the BOC-23 voltage.

2.3 Tubes Returned to Service

Steam generator A had 9 DSS's in tubes that were deplugged and returned to service. Steam generator B had 54 DSS's in tubes that were deplugged and returned to service. Because some plants have shown accelerated growth rates for indications in deplugged tubes, the growth rates used for Cycle 24 were adjusted for the deplugged tube data.

2.4 Probe Wear Criteria Implementation

The probe wear criteria approved by the NRC (Ref. 6.5) was applied during the April 2000 inspection. This reference provides the guidelines to be used for bobbin probe wear associated with voltage-based repair implementation. When a probe does not pass the 15% wear limit, this criteria requires that only tubes with indications above 75% of the repair limit inspected since the last successful probe wear check be re-inspected with a good probe. Since the repair limit for KNPP is 2.0 volts, all tubes containing indications above 1.5 volts that were originally inspected with a worn probe were re-inspected with a new probe. Reference 6.6

documents the results of the ARC probe wear monitoring for the April 2000 eddy current inspection.

The NRC requirements regarding probe wear monitoring during an ARC bobbin coil inspection were fully complied with during the April 2000 eddy current examination at KNPP.

Table 2-3
Average Measured Voltage Growth Rates, 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 23 (1998-2000) – 1.3375 EFPY						
Entire Voltage Range	1203	0.56	0.023	0.017	4.0	3.0
V_{BOC} < .75 Volts	934	0.43	0.034	0.025	7.9	5.9
>= .75 Volts	269	1.03	-0.016	-0.012	-1.6	-1.2
Cycle 22 (1997-1998) – 458.4 EFPD						
Entire Voltage Range	1056	0.55	0.015	0.012	2.7	2.2
V_{BOC} < .75 Volts	815	0.41	0.028	0.023	6.8	5.6
>= .75 Volts	241	1.00	-0.031	-0.025	-2.9	-2.3
Cycle 21 (1995-1997) – 472 EFPD						
Entire Voltage Range	968	0.56	0.029	0.022	5.1	3.9
V_{BOC} < .75 Volts	741	0.42	0.036	0.028	8.4	6.5
>= .75 Volts	227	1.02	0.006	0.004	0.6	0.4
Cycle 20 (1994-1995) – 319 EFPD						
Entire Voltage Range	709	0.54	0.028	0.032	5.1	5.9
V_{BOC} < .75 Volts	576	0.42	0.031	0.035	7.3	8.4
>= .75 Volts	133	1.09	-0.016	-0.018	-1.5	-1.7
Cycle 19 (1993-1994) – 325.7 EFPD						
Entire Voltage Range	572	0.61	0.002	0.003	0.4	0.4
V_{BOC} < .75 Volts	425	0.45	0.015	0.016	3.2	3.6
>= .75 Volts	147	1.08	-0.033	-0.037	-3.1	-.34
Cycle 18 (1992-1993) – 309 EFPD						
Entire Voltage Range	450	0.75	0.04	0.047	5.3	6.3
V_{BOC} < .75 Volts	279	0.49	0.05	0.059	10.2	12.1
>= .75 Volts	171	1.17	0.03	0.035	2.6	3.0
Cycle 17 (1991-1992) – 318 EFPD						
Entire Voltage Range	382	0.69	0.12	0.150	18.0	22.4
V_{BOC} < .75 Volts	261	0.49	0.12	0.150	24.0	29.9
>= .75 Volts	121	1.11	0.13	0.162	12.0	15.0
Cycle 16 (1990-1991) – 310 EFPD						
Entire Voltage Range	187	1.2	-0.24	-0.276	-20	-23.0
Cycle 15 (1989-1990) – 310 EFPD						
Entire Voltage Range	52	0.95	0.14	0.165	15	17.4
Cycle 14 (1988-1989) – 298 EFPD						
Entire Voltage Range	35	0.93	0.13	0.160	14	17.2
Cycle 13 (1987-1988) – 325 EFPD						
Entire Voltage Range	20	0.87	0.11	0.123	13	14.2

3.0 Bobbin Voltage Distributions

3.1 EOC-23 (As Found) Voltage Distributions

The measured voltages for the DSS indications detected during the April 2000 eddy current inspection were binned in 0.1 volt increments. The as found voltage distributions are used to determine the BOC-24 voltage distributions, per Section 3.4. Tables 3-1 and 3-2 show the voltage distributions.

It should be noted that five DSS's were reported using a .640WG (wide groove) bobbin probe. The .640WG probe was used to inspect the hot leg straight sections of some of the sleeved tubes. Since this is not the approved ARC probe, these intersections were inspected with a rotating coil and the tubes were plugged upon confirmation of ODSCC. Due to the differences in the voltage response of the .640 probe compared to the .720UL probe, a study was done to develop a correction factor to apply to the .640WG voltage. This study was done by comparing the voltage response of the 60% and 100%TW ASME holes in the calibration standard, using both probes. Of the two different runs that were compared, the .720UL voltage was 1.49 times higher than the .640WG voltage on the 100%TW hole and 1.27 times higher on the 60% hole. Therefore, a conservative correction factor of 1.5 was applied to the five .640WG signals before running the leak rate and probability of burst calculations.

3.2 Repaired Tubes

A total of 31 DSS's were removed from service by plugging during the April 2000 outage (17 in SG A and 14 in SG B). Most of these were plugged due to other indications in the tube, i.e., not related to the DSS calls. Two indications in one tube were removed from service due to a confirmed DSS greater than 2 volts. Seven indications in two other tubes were removed from service due to confirmed DSS's which couldn't be inspected with a .720" bobbin probe. Tables 3-1 and 3-2 include voltage distributions for these tubes.

3.3 Tubes Containing DSS Indications Left In Service

A total of 1235 DSS's were returned to service for Cycle 24 (333 in SG A and 902 in SG B). 1187 of these DSS's were either confirmed as crack-like with Plus Point or were not inspected with Plus Point. Of the other 48 DSS's which were returned to service, 47 were reported as NDF (No Defect Found) and 1 was reported as INR (Indication Not Reportable) from the Plus Point inspection.

3.4 BOC-24 Voltage Distributions

BOC-24 voltage distributions were calculated by applying a probability of detection (POD) factor to EOC-23 as found voltage distributions. In addition, indications removed from service were removed from the distributions, and indications that were deplugged and returned to service were added to the distribution. The NRC Generic Letter 95-05 specifies that a POD value of 0.6 should be used for voltage distribution projections. The relationship shown below was used to calculate the BOC-24 voltage distributions.

$$N_{BOC24(i)} = (N_{EOC23(i)} \div POD) - N_{repaired(i)} + N_{RTS(i)} \qquad \text{Eq. 3-1}$$

The resulting BOC-24 voltage distributions are shown in Tables 3-1 and 3-2 and Figures 3-1 and 3-2.

3.5 Voltage Growth Distributions

The analysis of measured growth rates is discussed in Section 2.2. In accordance with the NRC Generic Letter 95-05, voltage growth rates were evaluated for those intersections at which bobbin coil indications were identified at both the EOC-22 and EOC-23 examinations. The measured growth values were divided by the Cycle 23 operating interval of 1.3375 EFPY to obtain growth values in terms of ΔVolts per EFPY. Table 2-3 shows these results. For the purposes of tube integrity calculations (Section 4.0), negative growth values are conservatively re-assigned to zero as required by the Generic Letter. The growth distributions are shown in Tables 3-3 and 3-4 and Figures 3-7 and 3-8.

In the 1998 EPRI Database Update (Reference 6.11), it was determined that growth rates for indications whose tubes were deplugged and returned to service may exhibit a different growth rate than those that have been in service. Therefore, separate growth rates were determined for the tubes

that were deplugged and returned to service in 1998 and the tubes that have been in service for more than one cycle (see Table 3-3). These growth rate distributions were then combined based on the EPRI equation (Eq. 3-2):

$$n_{i,comb} = (n_{i,ag} \times N_a) \div n_{t,ag} + (n_{i,dg} \times N_{dp}) \div n_{t,dg} \qquad \text{Eq. 3-2}$$

where,

$n_{i,comb} \equiv$ number of indications in the ith bin of composite growth distribution,
$n_{i,ag} \equiv$ number of indications in the ith bin of active tube growth distribution,
$n_{i,dg} \equiv$ number of indications in the ith bin of deplugged tube growth distribution,
$N_a \equiv$ total number of indications in active tubes returned to service,
$N_{dp} \equiv$ total number of indications in deplugged tubes returned to service,
$n_{t,ag} \equiv$ total number of indications in the active tube growth distribution,
$n_{t,dg} \equiv$ total number of indications in the deplugged tube growth distribution.

Table 3-4 summarizes the composite growth rates. Because of the relatively small number of DSS calls in tubes that were returned to service, the composite Cycle 24 (projected) growth rate is heavily weighted towards the active tube growth rate. Note that since more than 200 plant-specific growth data points are available, the industry bounding data does not need to be implemented.

3.6 NDE Uncertainty Distributions

NDE uncertainties are taken into account for projecting the end-of-cycle indication voltages for the upcoming operating cycle. The NDE uncertainties used in the calculations of the EOC-24 voltages are described in Reference 6.7. The acquisition uncertainty was sampled from a normal distribution with a mean of zero, a standard deviation of 7%, and a cut-off limit of 15%. This cut-off value is based on the probe wear monitoring which was performed during the April 2000 inspection. The analyst uncertainty was sampled from a normal distribution with a mean of zero, a standard deviation of 10.3%, and no cut-off limit. The uncertainty distributions are shown in Table 3-8 and Figure 3-12.

3.7 Projected EOC-24 Voltage Distributions

The EOC-24 DSS bobbin voltage distributions were projected by applying a Monte Carlo mathematical sampling process to the BOC-24 data. This process involves applying randomly assigned uncertainty values along with a growth value to each of the BOC-24 indications. Each sampling of all of the BOC-24 indications in a steam generator is called a trial. The algorithm also normalizes for expected cycle length. An expected cycle length of 1.22 EFPY was used in the calculations. The output of this random sampling process is a calculated EOC-24 voltage for each BOC-24 indication in both steam generators. The data is binned in 0.1 volt increments. The resulting bin values are then divided by the number of trials to obtain the average number of EOC-24 indications per trial in each voltage bin. The projected EOC-24 voltage distributions shown in Table 3-9 and Figures 3-13 and 3-14 are based on 1 million trials.

Table 3-1
DSS Calls, EOC-23 And BOC-24 Voltage Distributions For SG A

Voltage Bin	EOC-23 As Found	w/ 0.6 POD Applied	Repaired by Plugging	EOC-23; deplugged & RTS for cycle 24	Adj. Count at BOC-24	DSS's Retuned to Service	
						Crack-like or not Insp w/ RPC	Total
0.1	0	0.00	0	0	0.00	0	0
0.2	24	40.00	1	0	39.00	24	24
0.3	54	90.00	1	0	89.00	52	52
0.4	55	91.67	1	0	90.67	54	54
0.5	51	85.00	1	0	84.00	49	50
0.6	46	76.67	3	0	73.67	33	43
0.7	27	45.00	1	1	45.00	25	27
0.8	27	45.00	1	1	45.00	25	27
0.9	15	25.00	2	2	25.00	15	15
1.0	11	18.33	0	4	22.33	14	15
1.1	4	6.67	1	0	5.67	3	3
1.2	5	8.33	0	0	8.33	4	5
1.3	6	10.00	1	0	9.00	4	5
1.4	3	5.00	0	0	5.00	3	3
1.5	1	1.67	1	0	0.67	0	0
1.6	4	6.67	1	0	5.67	2	3
1.7	3	5.00	0	0	5.00	3	3
1.8	3	5.00	0	1	6.00	4	4
1.9	1	1.67	1	0	0.67	0	0
2.0	0	0.00	0	0	0.00	0	0
2.8	0	0.00	0	0	0.00	0	0
2.9	0	0.00	0	0	0.00	0	0
3.0	0	0.00	0	0	0.00	0	0
3.1	0	0.00	0	0	0.00	0	0
3.2	0	0.00	0	0	0.00	0	0
3.3	0	0.00	0	0	0.00	0	0
3.4	0	0.00	0	0	0.00	0	0
[illegible]	1	1.67	1	0	0.67	0	0
[illegible]	0	[illegible]	0	0	0.00	0	0
>3.5	0	[illegible]	0	0	0.00	0	0
Total	341	568.33	17	9	560.33	314	333

Table 3-2
DSS Calls, EOC-23 And BOC-24 Voltage Distributions For SG B

Voltage Bin	EOC-23 As Found	w/ 0.6 POD Applied	Repaired by Plugging	EOC-23; deplugged & RTS for cycle 24	Adj. Count at BOC-24	DSS's Retuned to Service	
						Crack-like or not Insp w/ RPC	Total
0.1	0	0.00	0	0	0.00	0	0
0.2	31	51.67	1	0	50.67	30	30
0.3	109	181.67	6	2	177.67	105	105
0.4	121	201.67	2	7	206.67	126	126
0.5	146	243.33	2	8	249.33	149	152
0.6	129	215.00	0	3	218.00	125	132
0.7	77	128.33	0	6	134.33	75	83
0.8	65	108.33	0	4	112.33	62	69
0.9	49	81.67	1	2	82.67	50	50
1.0	32	53.33	1	4	56.33	35	35
1.1	27	45.00	0	3	48.00	30	30
1.2	22	36.67	0	5	41.67	25	27
1.3	16	26.67	0	4	30.67	19	20
1.4	10	16.67	0	0	16.67	10	10
1.5	8	13.33	0	0	13.33	8	8
1.6	4	6.67	0	2	8.67	6	6
1.7	10	16.67	0	2	18.67	12	12
1.8	2	3.33	0	2	5.33	4	4
1.9	3	5.00	1	0	4.00	2	3
2.0	0	0.00	0	0	0.00	0	0
2.8	0	0.00	0	0	0.00	0	0
2.9	1	1.67	0	0	1.67	0	0
3.0	0	0.00	0	0	0.00	0	0
3.1	0	0.00	0	0	0.00	0	0
3.2	0	0.00	0	0	0.00	0	0
3.3	0	0.00	0	0	0.00	0	0
3.4	0	0.00	0	0	0.00	0	0
3.5	0	0.00	0	0	0.00	0	0
3.6	0	0.00	0	0	0.00	0	0
>3.6	0	0.00	0	0	0.00	0	0
Total	862	1436.67	14	54	1476.67	873	902

Table 3-3
DSS Indications Growth Statistics for Cycle 23 (1998-2000) Per EFPY

Voltage Growth Per EFPY	Active Tubes Growth				Voltage Growth Per EFPY	Deplugged (In 1998) Tubes Growth			
	Number of Ind's		Cumulative Percent			Number of Ind's		Cumulative Percent	
	SG A	SG B	SG A	SG B		SG A	SG B	SG A	SG B
<=-0.50	0	0	0.00	0.00	<=-0.50	0	1	0.00	0.02
-0.49 to -0.40	1	1	0.00	0.00	-0.49 to -0.40	0	0	0.00	0.02
-0.39 to -0.30	3	4	0.01	0.01	-0.39 to -0.30	0	0	0.00	0.02
-0.29 to -0.20	7	19	0.03	0.03	-0.29 to -0.20	0	2	0.00	0.05
-0.19 to -0.10	24	70	0.10	0.12	-0.19 to -0.10	0	4	0.00	0.11
-0.09 to 0.00	117	296	0.46	0.49	-0.09 to 0.00	1	18	0.20	0.39
0.01 to 0.10	120	273	0.81	0.83	0.01 to 0.10	3	20	0.80	0.70
0.11 to 0.20	41	96	0.94	0.95	0.11 to 0.20	0	9	0.80	0.84
0.21 to 0.30	12	24	0.97	0.98	0.21 to 0.30	0	6	0.80	0.94
0.31 to 0.40	3	3	0.98	0.99	0.31 to 0.40	0	1	0.80	0.95
0.41 to 0.50	4	6	0.99	0.99	0.41 to 0.50	1	2	1.00	0.98
0.51 to 0.60	1	4	1.00	1.00	0.51 to 0.60	0	0	1.00	0.98
0.61 to 0.70	1	0	1.00	1.00	0.61 to 0.70	0	1	1.00	1.00
0.71 to 0.80	0	0	1.00	1.00	0.71 to 0.80	0	0	1.00	1.00
0.81 to 0.90	0	0	1.00	1.00	0.81 to 0.90	0	0	1.00	1.00
0.91 to 1.00	0	0	1.00	1.00	0.91 to 1.00	0	0	1.00	1.00
>1.00	0	0	1.00	1.00	>1.00	0	0	1.00	1.00
Total	334	796	-	-	Total	5	64	-	-

Table 3-4
Combined Growth Data for Active and Deplugged Tubes Projected For Cycle 23[1]

Voltage Growth Per EFPY	Composite Growth (per EPRI)			
	Number of Ind's		Cumulative Percent	
	SG A	SG B	SG A	SG B
<=-0.50	0.00	0.84	0.00	0.00
-0.49 to -0.40	1.02	1.08	0.00	0.00
-0.39 to -0.30	3.06	4.33	0.01	0.01
-0.29 to -0.20	7.15	22.26	0.03	0.03
-0.19 to -0.10	24.50	79.18	0.10	0.12
-0.09 to 0.00	121.25	335.73	0.45	0.48
0.01 to 0.10	127.91	312.51	0.81	0.83
0.11 to 0.20	41.86	111.55	0.93	0.95
0.21 to 0.30	12.25	31.05	0.97	0.98
0.31 to 0.40	3.06	4.09	0.98	0.99
0.41 to 0.50	5.88	8.18	0.99	0.99
0.51 to 0.60	1.02	4.33	1.00	1.00
0.61 to 0.70	1.02	0.84	1.00	1.00
0.71 to 0.80	0.00	0.00	1.00	1.00
0.81 to 0.90	0.00	0.00	1.00	1.00
0.91 to 1.00	0.00	0.00	1.00	1.00
>1.00	0.00	0.00	1.00	1.00
Total	350	916	-	-

1: Note that the growth rate distributions shown in Table 3-4 are weighted based on the number of indications in each category that were returned to service for Cycle 24.

Table 3-5
Voltage Growth Statistics for Cycle 23 on an EFPY Basis

Delta Volts	Steam Generator A			Steam Generator B			Combined		
	Cycle 22	Cycle 23		Cycle 22	Cycle 23		Cycle 22	Cycle 23	
	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF
<=-0.50	0.000	0	0.000	0.004	1	0.001	0.003	1	0.001
-0.49 to -0.40	0.000	1	0.003	0.007	1	0.002	0.005	2	0.003
-0.39 to -0.30	0.016	3	0.012	0.013	4	0.007	0.014	7	0.008
-0.29 to -0.20	0.036	7	0.032	0.037	21	0.031	0.037	28	0.032
-0.19 to -0.10	0.138	24	0.103	0.139	74	0.117	0.139	98	0.113
-0.09 to 0.00	0.474	118	0.451	0.446	314	0.483	0.454	432	0.474
0.01 to 0.10	0.809	123	0.814	0.824	293	0.823	0.820	416	0.821
0.11 to 0.20	0.941	41	0.935	0.959	105	0.945	0.953	146	0.942
0.21 to 0.30	0.987	12	0.971	0.989	30	0.980	0.989	42	0.977
0.31 to 0.40	0.993	3	0.979	0.997	4	0.985	0.996	7	0.983
0.41 to 0.50	1.000	5	0.994	0.999	8	0.994	0.999	13	0.994
0.51 to 0.60	1.000	1	0.997	1.000	4	0.999	1.000	5	0.998
0.61 to 0.70	1.000	1	1.000	1.000	1	1.000	1.000	2	1.000
0.71 to 0.80	1.000	0	1.000	1.000	0	1.000	1.000	0	1.000
0.81 to 0.90	1.000	0	1.000	1.000	0	1.000	1.000	0	1.000
0.91 to 1.00	1.000	0	1.000	1.000	0	1.000	1.000	0	1.000
>1.00	1.000	0	1.000	1.000	0	1.000	1.000	0	1.000
Total	-	339	-	-	860	-	-	1199	-

Table 3-6
Summary of Largest Voltage Growths for Cycle 23

Tube Information				Bobbin Voltage			New Ind?	Deplugged BOC-23?	RPC Insp?/ RPC Conf?
SG	Row	Col	Elev	BOC-23	EOC-23	Growth			
SG A	13	29	01H	0.28	1.16	0.88	N	N	Y / N
SG B	27	79	02H	0.47	1.34	0.87	N	Y	N / N
SG B	4	86	03H	0.49	1.18	0.69	N	N	Y / N
SG B	35	77	06H	1.12	1.81	0.69	N	N	Y / N
SG B	38	53	04C	1.19	1.88	0.69	N	N	N / N
SG B	36	51	02C	0.41	1.09	0.68	N	N	N / N
SG A	23	24	01H	0.89	1.56	0.67	N	N	N / N
SG A	4	38	03H	0.16	0.82	0.66	N	Y	Y / N
SG B	27	18	05C	0.65	1.29	0.64	N	N	N / N
SG B	10	68	03H	0.29	0.9	0.61	N	N	N / N
SG B	14	14	02C	0.47	1.07	0.60	N	N	N / N
SG A	23	7	06C	0.37	0.96	0.59	N	N	N / N
SG B	38	39	06C	0.62	1.21	0.59	N	Y	N / N
SG A	11	57	02C	0.68	1.25	0.57	N	N	N / N
SG A	40	26	01H	1.15	1.71	0.56	N	N	N / N
SG A	27	11	06H	0.24	0.8	0.56	N	N	N / N
SG B	13	31	01C	0.46	1.02	0.56	N	N	N / N
SG B	30	75	06C	0.57	1.12	0.55	N	N	N / N
SG B	20	66	06C	0.60	1.14	0.54	N	N	N / N
SG B	38	35	04H	0.53	1.07	0.54	N	Y	N / N
SG A	42	29	02H	0.53	1.05	0.52	N	N	Y / Y
SG B	43	48	07C	0.42	0.9	0.48	N	N	N / N
SG A	33	16	01H	1.33	1.79	0.46	N	N	N / N
SG B	27	80	03H	0.25	0.7	0.45	N	Y	N / N
SG B	31	73	03H	1.23	1.67	0.44	N	N	N / N
SG B	33	56	07H	0.97	1.41	0.44	N	N	N / N
SG A	27	55	01C	0.34	0.76	0.42	N	N	N / N
SG B	17	71	06C	0.20	0.6	0.40	N	N	N / N
SG B	38	35	02C	0.48	0.88	0.40	N	Y	N / N

Table 3-7
TSP Indication Distributions for Tubes In Service During Cycle 23

TSP	Steam Generator A					Steam Generator B				
	Number of Indications	Max Voltage	Avg Voltage	Max Growth	Avg Growth	Number of Indications	Max Voltage	Avg Voltage	Max Growth	Avg Growth
01H	64	1.79	0.77	0.88	0.05	22	1.64	0.86	0.39	0.05
02H	27	1.05	0.51	0.52	-0.02	28	2.85	0.57	0.87	0.04
03H	12	1.23	0.51	0.66	0.07	40	1.67	0.57	0.69	0.06
04H	10	0.97	0.42	0.21	0.01	46	1.43	0.47	0.54	0.01
05H	8	0.65	0.39	0.31	0.03	32	0.89	0.43	0.32	0.01
06H	18	0.95	0.41	0.56	0.01	27	1.81	0.47	0.69	0.05
07H	13	0.9	0.47	0.19	0.02	40	1.41	0.54	0.44	0.02
01C	38	1.04	0.55	0.42	0.04	96	1.72	0.63	0.56	0.02
02C	32	1.88	0.55	0.57	0.05	138	1.71	0.63	0.68	0.04
03C	10	3.42	0.71	0.25	0.09	54	1.27	0.56	0.32	0.03
04C	6	0.53	0.37	0.13	0.02	57	1.88	0.61	0.69	0.01
05C	13	0.99	0.59	0.21	0.03	50	1.65	0.61	0.64	-0.02
06C	34	1.52	0.54	0.59	0.02	144	1.83	0.65	0.59	0.00
07C	56	1.7	0.49	0.35	0.02	88	1.69	0.64	0.48	0.01
Total	341	-	-	-	-	862	-	-	-	-

TSP	Composite of Both Steam Generators				
	Number of Indications	Max Voltage	Avg Voltage	Max Growth	Avg Growth
01H	86	1.79	0.80	0.88	0.05
02H	55	2.85	0.54	0.87	0.01
03H	52	1.67	0.56	0.69	0.07
04H	56	1.43	0.46	0.54	0.01
05H	40	0.89	0.42	0.32	0.02
06H	45	1.81	0.44	0.69	0.03
07H	53	1.41	0.52	0.44	0.02
01C	134	1.72	0.61	0.56	0.02
02C	170	1.88	0.62	0.68	0.04
03C	64	3.42	0.58	0.32	0.04
04C	63	1.88	0.59	0.69	0.01
05C	63	1.65	0.61	0.64	-0.01
06C	178	1.83	0.62	0.59	0.01
07C	144	1.70	0.58	0.48	0.01
Total	1203	-	-	-	-

Table 3-8
NDE Uncertainty Distributions

Analyst Uncertainty

Percent Variation	Cumulative Probability
-40.0%	0.00005
-38.0%	0.00011
-36.0%	0.00024
-34.0%	0.00048
-32.0%	0.00095
-30.0%	0.00179
-28.0%	0.00328
-26.0%	0.00580
-24.0%	0.00990
-22.0%	0.01634
-20.0%	0.02608
-18.0%	0.04027
-16.0%	0.06016
-14.0%	0.08704
-12.0%	0.12200
-10.0%	0.16581
-8.0%	0.21867
-6.0%	0.28011
-4.0%	0.34888
-2.0%	0.42302
0.0%	0.50000
2.0%	0.57698
4.0%	0.65112
6.0%	0.71989
8.0%	0.78133
10.0%	0.83419
12.0%	0.87800
14.0%	0.91296
16.0%	0.93984
18.0%	0.95973
20.0%	0.97392
22.0%	0.98366
24.0%	0.99010
26.0%	0.99420
28.0%	0.99672
30.0%	0.99821
32.0%	0.99905
34.0%	0.99952
36.0%	0.99976
38.0%	0.99989
40.0%	0.99995

Std Deviation = 10.3%
Mean = 0.0%
No Cutoff

Acquisition Uncertainty

Percent Variation	Cumulative Probability
<-15.0%	0.00000
-15.0%	0.01606
-14.0%	0.02275
-13.0%	0.03165
-12.0%	0.04324
-11.0%	0.05804
-10.0%	0.07656
-9.0%	0.09927
-8.0%	0.12655
-7.0%	0.15866
-6.0%	0.19568
-5.0%	0.23753
-4.0%	0.28385
-3.0%	0.33412
-2.0%	0.38755
-1.0%	0.44320
0.0%	0.50000
1.0%	0.55680
2.0%	0.61245
3.0%	0.66588
4.0%	0.71615
5.0%	0.76247
6.0%	0.80432
7.0%	0.84134
8.0%	0.87345
9.0%	0.90073
10.0%	0.92344
11.0%	0.94196
12.0%	0.95676
13.0%	0.96835
14.0%	0.97725
15.0%	0.98394
>15.0%	1.00000

Std Deviation = 7.0%
Mean = 0.0%
Cutoff = +/- 15.0%

Table 3-9
Projected EOC-24 Bobbin Voltage Distributions

Voltage Bin	Projected No. of DSS Indications at EOC-24	
	SG A	SG B
0.1	0.847	1.188
0.2	18.820	29.297
0.3	49.311	96.386
0.4	70.774	156.279
0.5	78.156	197.375
0.6	74.120	203.258
0.7	63.084	177.894
0.8	50.922	142.640
0.9	39.804	110.697
1	29.565	85.164
1.1	21.180	66.294
1.2	15.060	51.928
1.3	10.916	40.214
1.4	8.223	30.622
1.5	6.477	23.213
1.6	5.340	17.750
1.7	4.506	13.624
1.8	3.741	10.303
1.9	2.936	7.497
2	2.146	5.171
2.1	1.465	3.371
2.2	0.943	2.090
2.3	0.578	1.253
2.4	0.341	0.745
2.5	0.196	0.464
2.6	0.110	0.319
2.7	0.063	0.253
2.8	0.039	0.225
2.9	0.030	0.209
3	0.031	0.194
3.1	0.036	0.172
3.2	0.045	0.147
3.3	0.053	0.120
3.4	0.058	0.094
3.5	0.061	0.070
3.6	0.061	0.052
3.7	0.057	0.037
3.8	0.051	0.025
3.9	0.045	0.017
4	0.037	0.011
>4	0.123	0.020
Total	560.349	1476.679

Figure 3-1

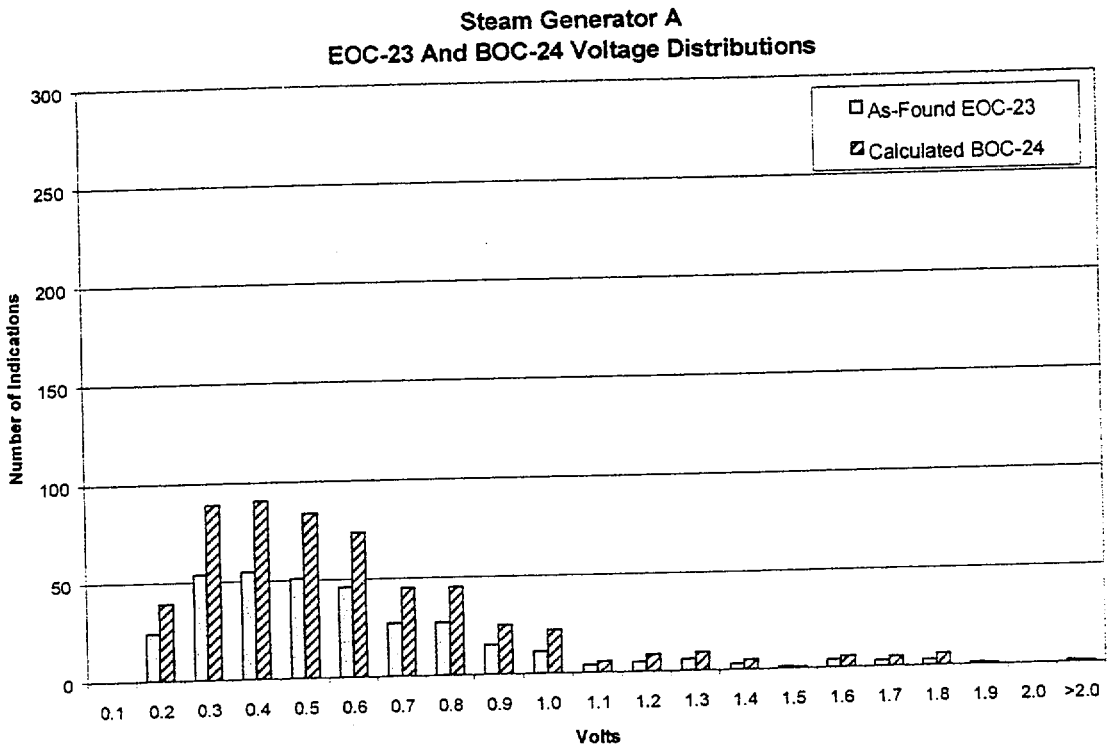


Figure 3-2

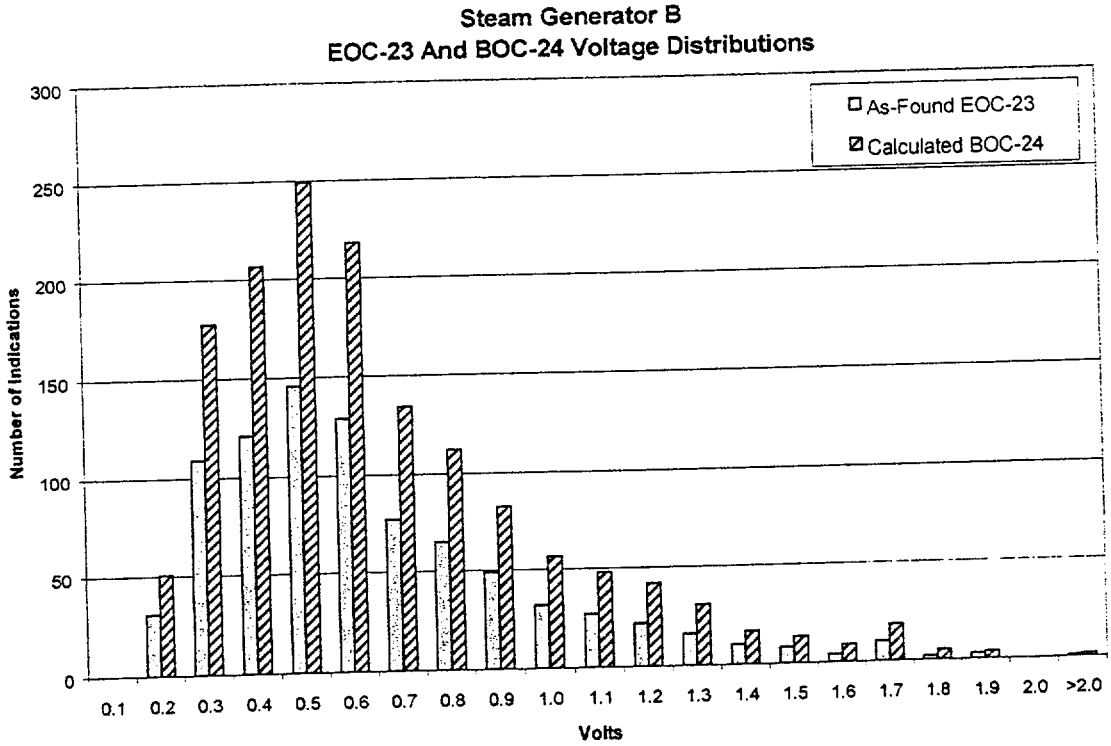


Figure 3-3

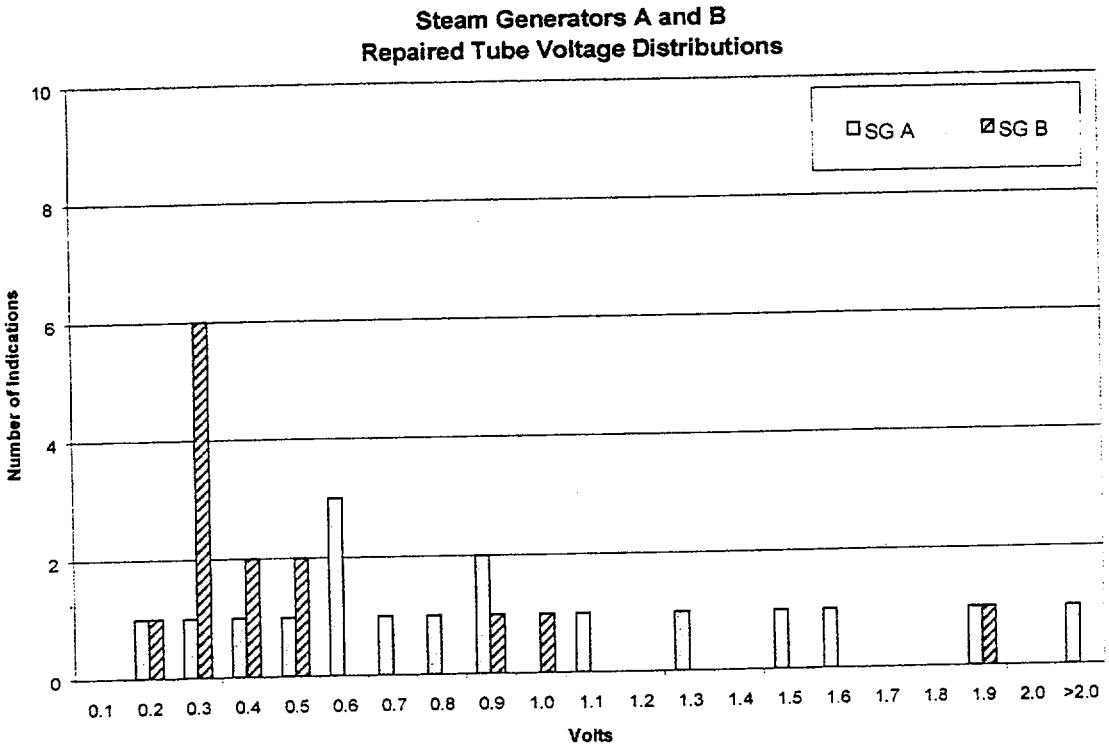


Figure 3-4

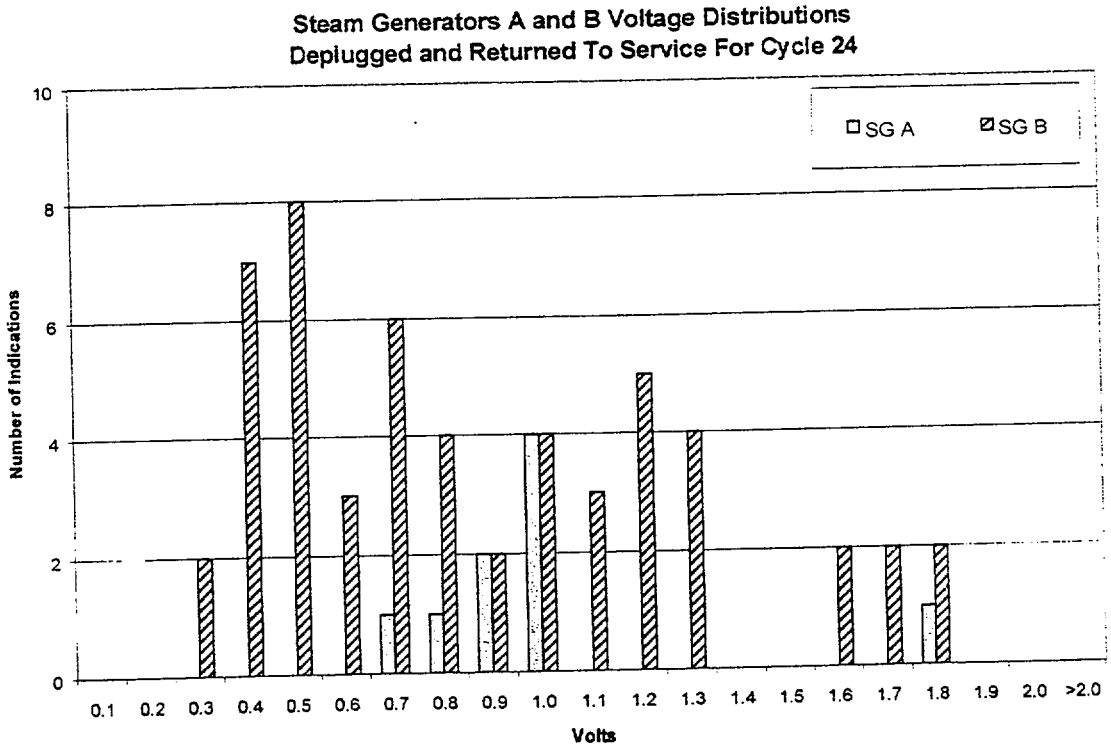


Figure 3-5

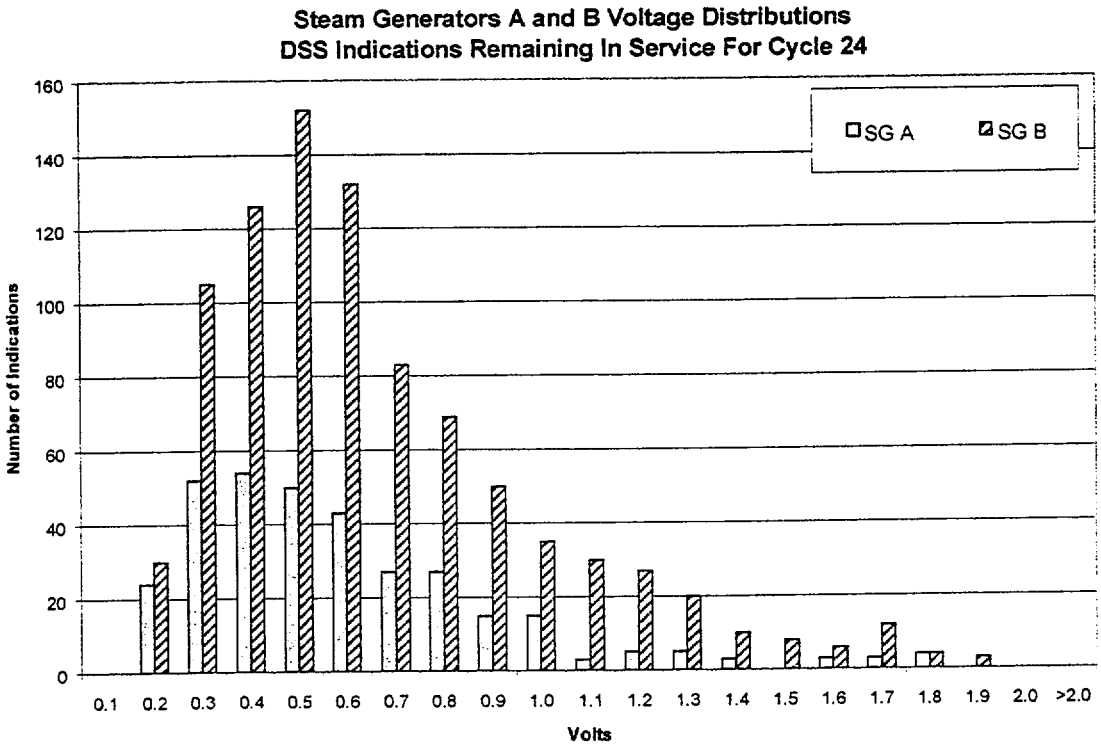


Figure 3-6

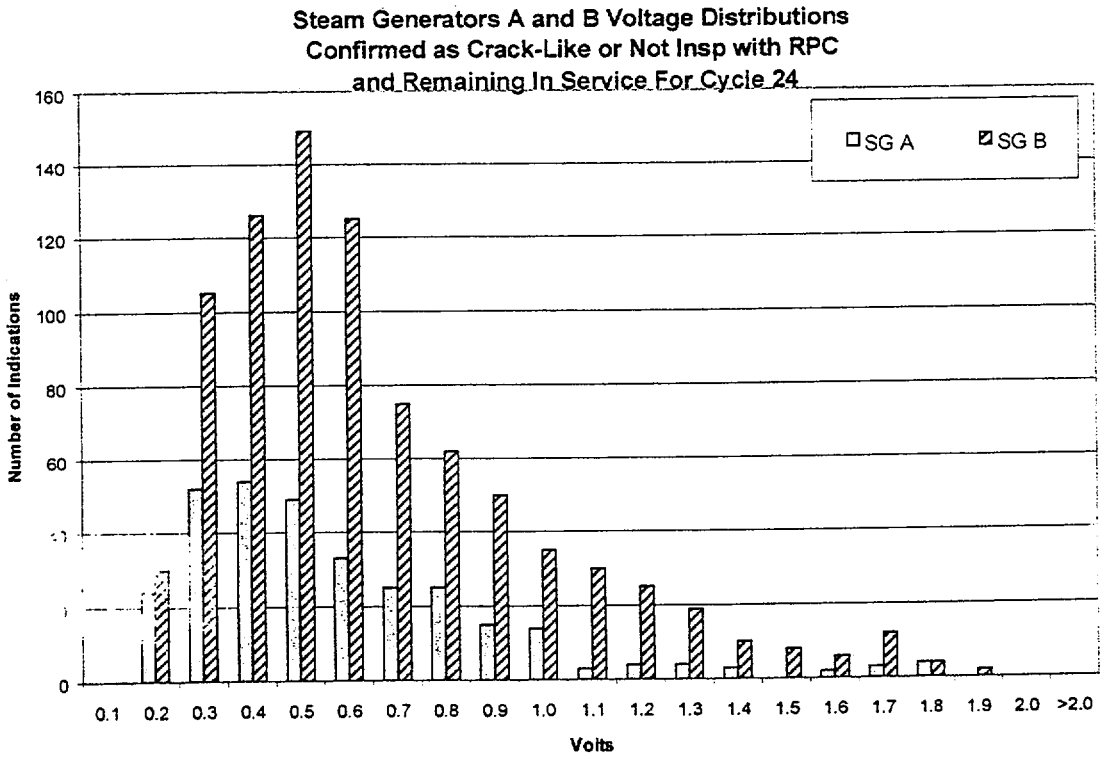


Figure 3-7

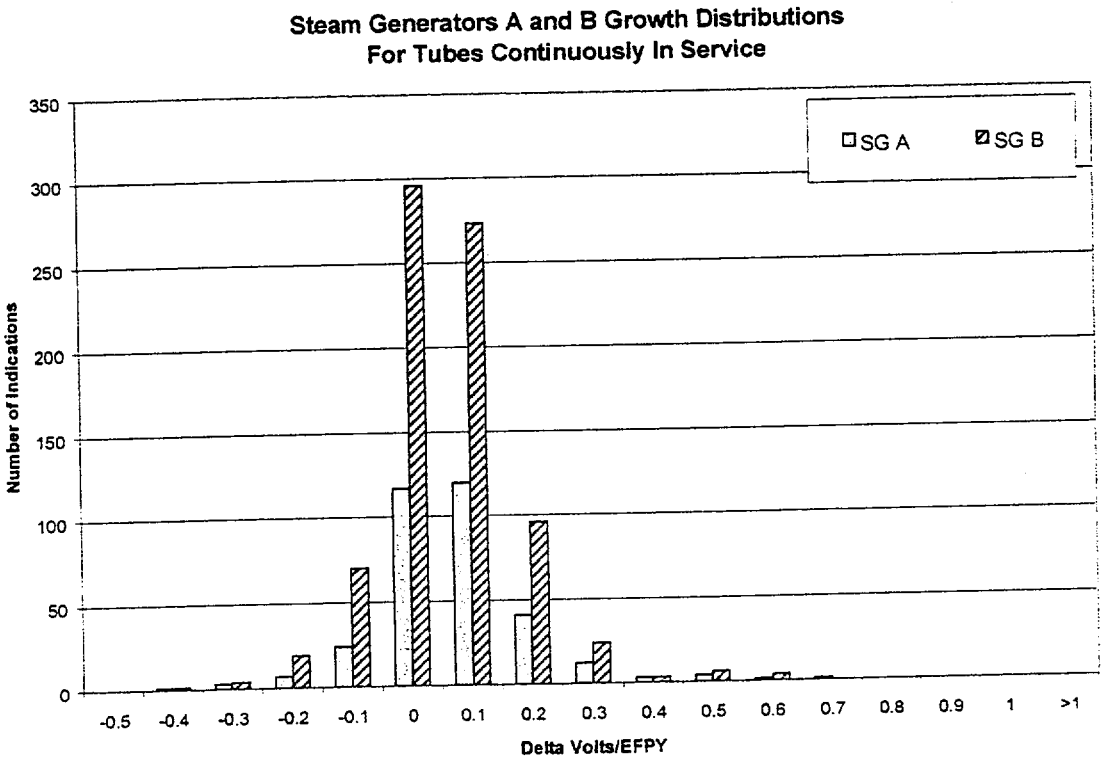


Figure 3-8

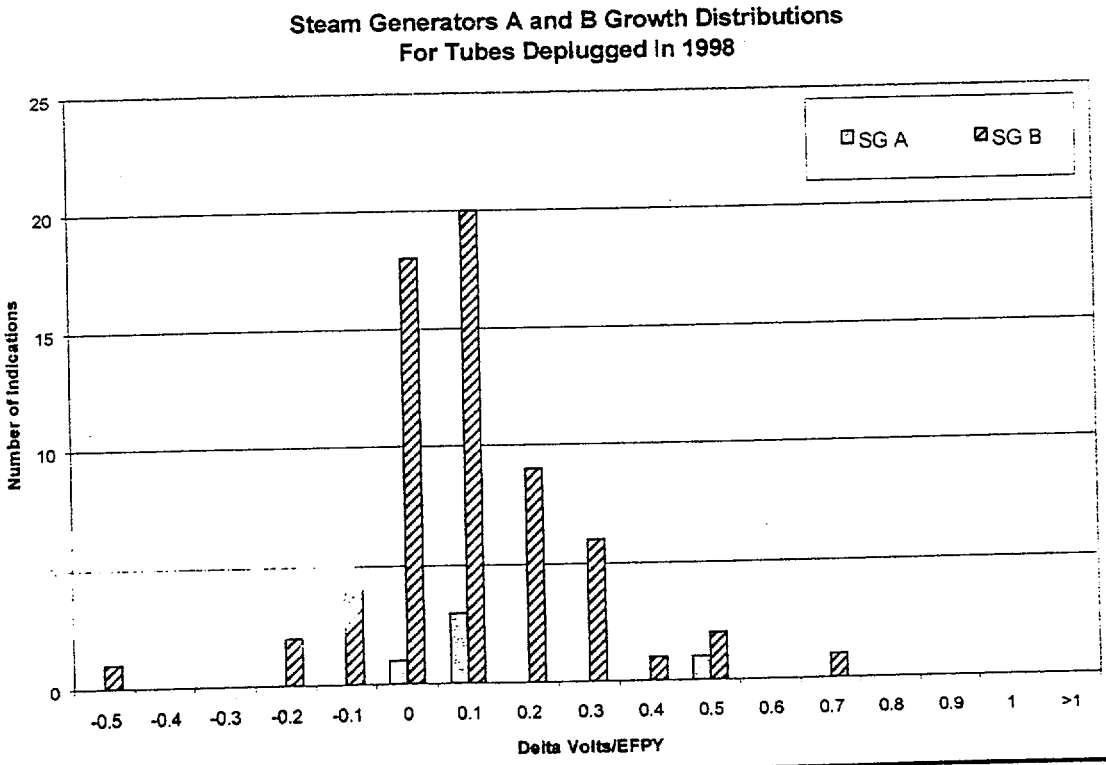


Figure 3-9

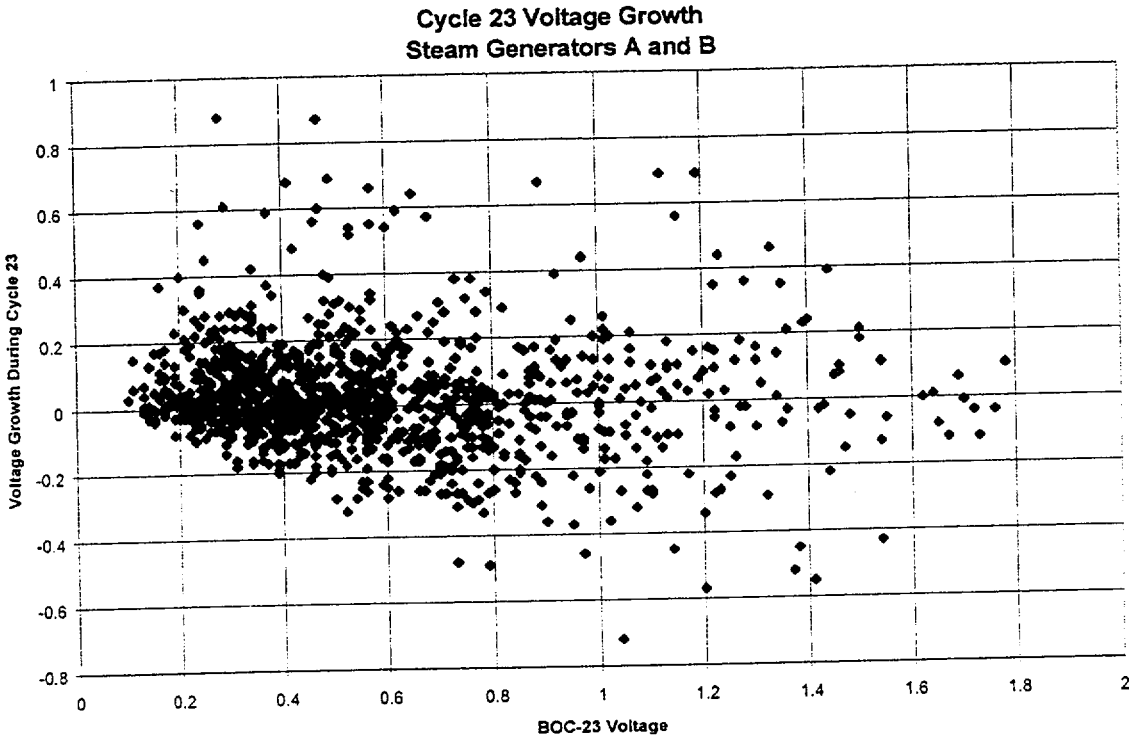

Cycle 23 Voltage Growth
Steam Generators A and B
Voltage Growth During Cycle 23
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
BOC-23 Voltage

Figure 3-10

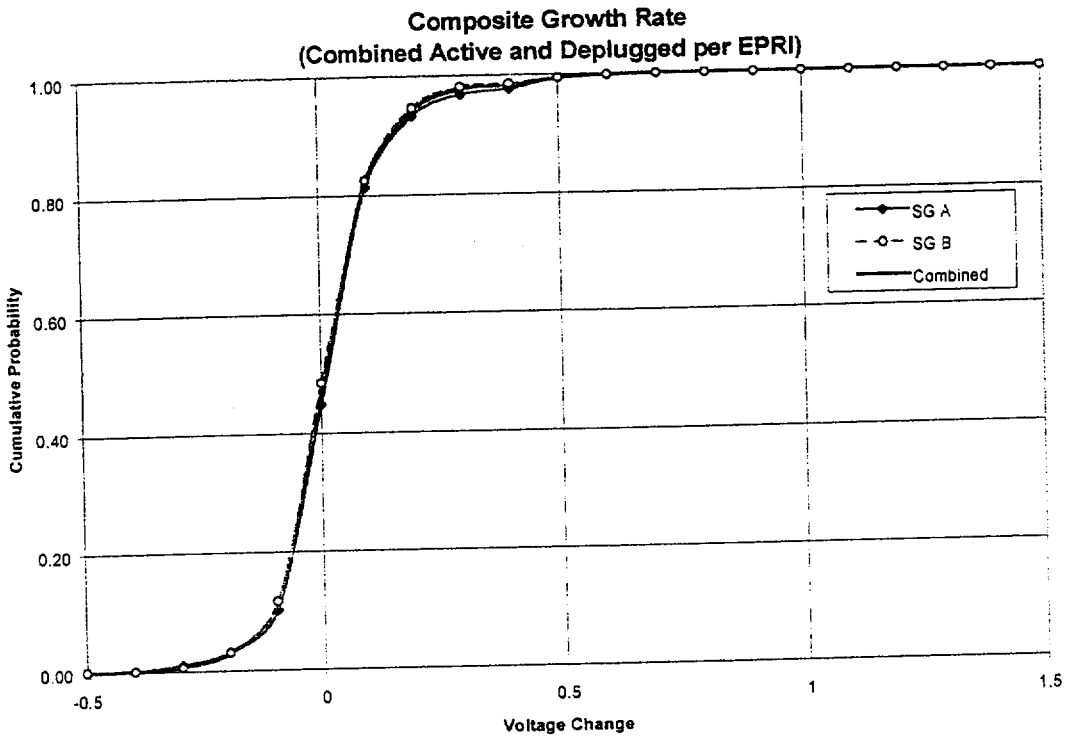


Figure 3-11

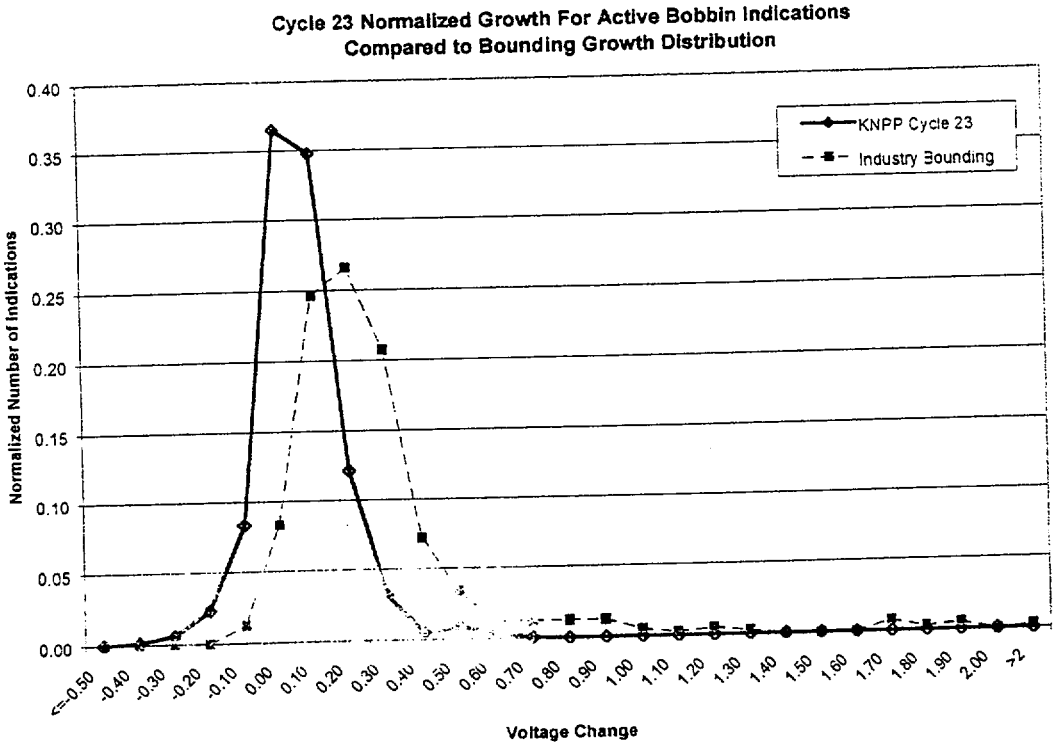


Figure 3-12

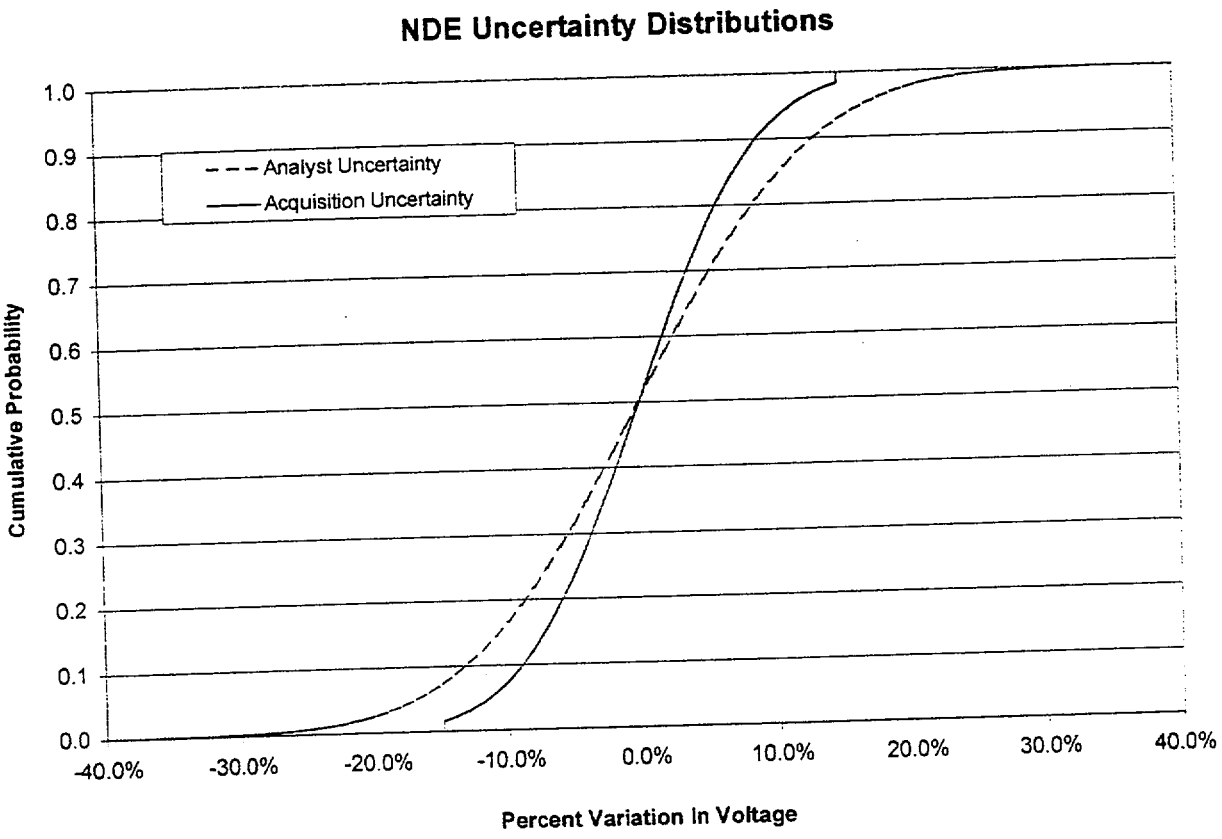

NDE Uncertainty Distributions
Analyst Uncertainty
Acquisition Uncertainty
Cumulative Probability
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-40.0%
-30.0%
-20.0%
-10.0%
0.0%
10.0%
20.0%
30.0%
40.0%
Percent Variation In Voltage

Figure 3-13

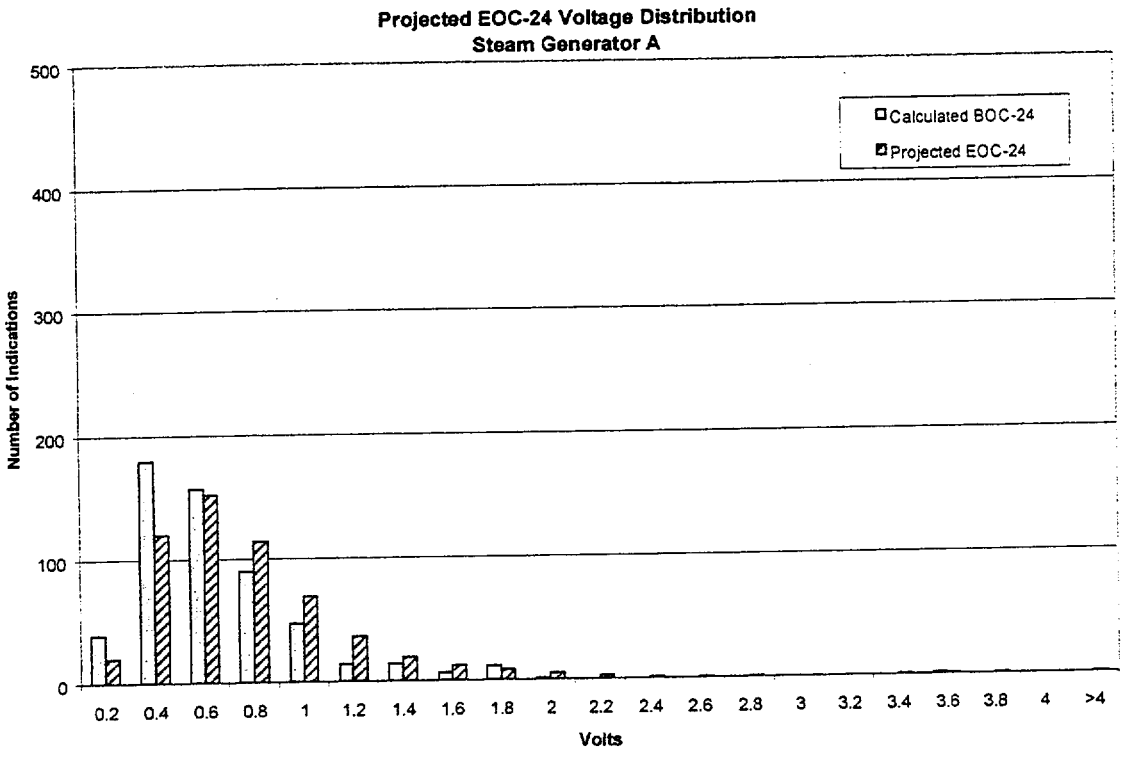
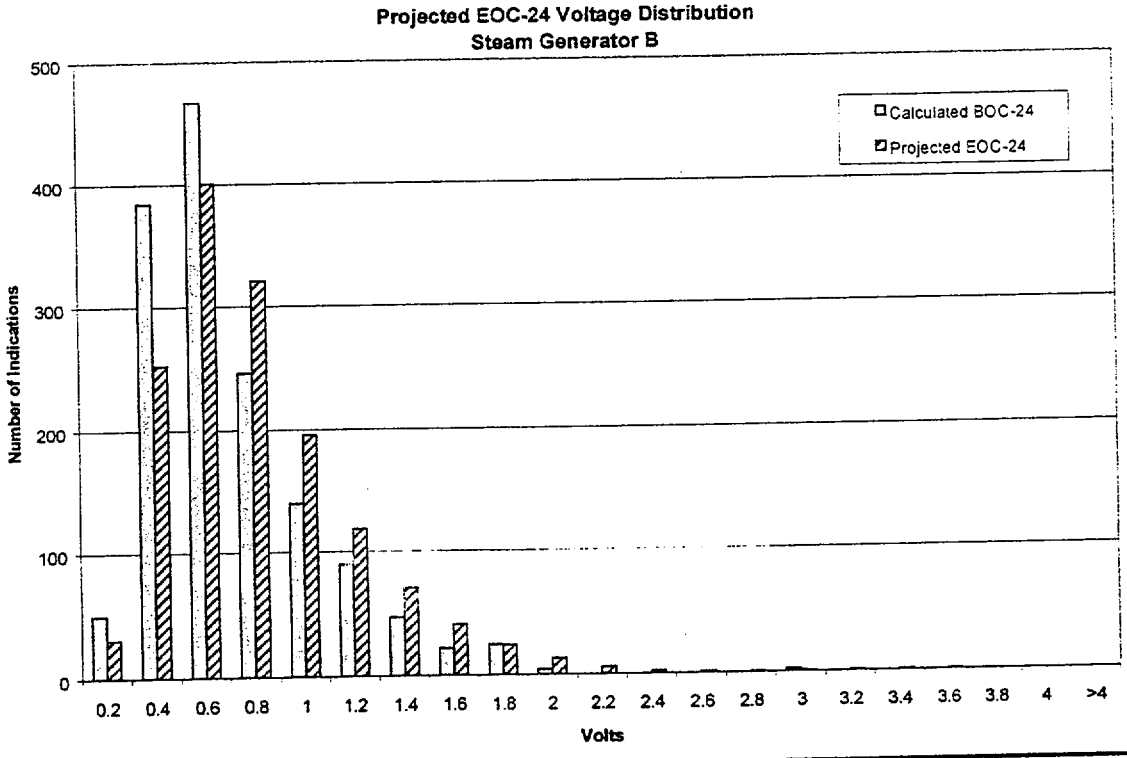


Figure 3-14



4.0 Correlation Parameters and Cycle Length Inputs

4.1 Overview

The leak and burst correlations utilized in the analyses presented in this report are based on the References 6.3 and 6.11. The leak rate correlation for a Main Steam Line Break (MSLB) ΔP of 2560 psid was used in the analysis. The correlations have been developed specifically for the evaluation of ODSCC indications at TSP locations in Model 51 steam generators and relate bobbin voltage amplitudes, free span burst pressure, probability of leakage and associated leak rates to assess tube integrity.

4.2 Burst Pressure Versus Voltage Correlation

For the burst pressure versus voltage correlation, the database contained in Reference 6.3 meets all NRC Generic Letter 95-05 requirements and was used in these calculations. The FTI computer simulation was utilized to predict the POB at the end of Cycle 24 under MSLB conditions based upon the input parameters shown in Table 4-1 (from Ref. 6.3, Table 6-6).

Table 4-1
Tube Burst Pressure vs. Bobbin Amplitude Correlation

$$P_B = \alpha_1 + \alpha_2 \log(Volts)$$

Parameter	Database
α_1	8.261536
α_2	-2.61495
r^2	82.3%
σ_{Error}	0.89837
N (data pairs)	91
p Value for α_2	1.6×10^{-35}
Reference σ_f	75

4.3 Leak Rate and Probability of Leakage Correlations

As documented in Section 1.3 and Reference 6.10, a leak rate correlation can now be applied to 7/8" tubes. Reference 6.11 presents the results of the regression analysis for the voltage-dependent leak rate correlation using the updated leak rate database for 7/8" tubes. It is shown that the one-sided p-value for the slope parameter in the voltage dependent leak rate correlation is 3.5% which is below the 5% threshold for an acceptable correlation specified in Generic Letter 95-05.

The methodology used in the calculation of these parameters is consistent with the NRC criteria in Reference 6.1. The Probability of Leak (POL) and leak rate correlation parameters used in this analysis are shown in Tables 4-2 and 4-3. The POL parameters are taken directly from Reference 6.3. The leak rate parameters are taken directly from Reference 6.11

Table 4-2
7/8" Tube Probability of Leak Correlation

$$Pr(Leak) = \{1 + e^{-[\beta_1 + \beta_2 \log(V)]}\}^{-1}$$

Parameter	Database
β_1	-4.31236
β_2	4.21125
V_{11} (1)	0.67152
V_{12}	-0.59145
V_{22}	0.59172
No. of Data Points	137
Deviance	78.81
Pearson SD	75.0%

Notes:
(1) Parameters V_{ij} are elements of the covariance matrix of the coefficients, β_i, of the regression equation.
(2) Degrees of freedom.

Table 4-3
Leak Rate Database for 7/8" Tube ARC Applications

$$Q = 10^{[b_3 + b_4 \log(volts)]}$$

Parameter	Database with A1&A2
Intercept, b_3	-0.526882
Slope, b_4	0.987179
Index of Deter, r^2	11.7%
Residuals, σ_{Error} (b_5)	0.808109
Data Pairs, N	29
Mean of Log(V)	1.1544
SS of Log(V)	2.3974
p Value for b_4	3.5%
V_{11} (1)	0.38550
V_{12}	-0.31445
V_{22}	0.27240

(1) Parameters V_{ij} are elements of the covariance matrix of the coefficients, β_i, of the regression equation and were calculated by FTI.

4.4 Cycle Operating Period

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

Cycle 23 - BOC-23 to EOC-23: 1.3375 EFPY (actual).
Cycle 24 - BOC-24 to EOC-24: 1.22 EFPY (projected).

5.0 Tube Integrity Method and Evaluations

The Monte Carlo analyses used to calculate the SLB leak rates and tube burst probabilities for the projected EOC-24 voltage distributions are consistent with the methods used in Reference 6.7. The FTI Monte Carlo analysis methodology is described in References 6.8 and 6.9. In general, the methodology involves application of statistical correlations for burst pressure, probability of leakage and leak rate to a measured or calculated EOC distribution to estimate the likelihood of tube burst and primary-to-secondary leakage during a postulated SLB event. The Monte Carlo analyses account for uncertainties associated with the burst pressure, leak rate probability, and leak rate correlations. NDE and material properties uncertainties are also similarly included.

This section presents the results of analyses carried out to predict leak rates and tube burst probabilities for postulated SLB conditions for the projected EOC-24 voltage distributions. SG B, with the largest total number of indications as well as indications over 1 volt, is expected to yield the limiting SLB leak rate and burst probability for Cycle 24.

The FTI Monte Carlo simulation code uses separate executable files for the probability of burst and leak rate calculations, which were verified for use in safety-related calculations in this document. This verification is FTI proprietary and is required whenever "open shop" codes are used for safety-related calculations.

5.1 Leak Rate and Tube Burst Probability for EOC-24

Calculations to predict SLB leak rate and tube burst probability for both Kewaunee steam generators at the EOC-24 were performed using the conservative POD value of 0.6 and calculated growth rates per Section 3.5 of this report. The leak and burst results for both steam generators are given in Table 5-1.

The limiting EOC-24 SLB leak rate, 1.92 gpm (room temperature) was predicted for steam generator B. This was expected as Steam Generator B has the larger number of indications. This limiting leak rate value is below the allowable SLB leakage limit of 2.69 gpm.

The limiting burst probability, 7.0×10^{-5}, was predicted for Steam Generator B. It is two orders of magnitude below the NRC reporting guideline of 10^{-2}.

Table 5-1
Tube Leak Rate and Burst Probability at EOC-24
for 1 Million Simulations using an Expected EFPY of 1.22

SG	POD	Number of Indications at EOC-24[1]	Probability of Burst		SLB Leak[3,5] Rate (gpm)
			Best Estimate[2]	95%UCL[4] (1 or More failures)	
A	0.6	560.35	2.4×10^{-5}	3.4×10^{-5}	0.61
B	0.6	1476.68	5.6×10^{-5}	7.0×10^{-5}	1.92
Acceptance Criteria →				1.0×10^{-2}	2.69[6]

Notes: (1) Adjusted for POD.
(2) Best Estimate is the number of trials with a failure divided by the number of trials.
(3) Equivalent volumetric rate at room temperature.
(4) The 95% Upper Confidence Limit (UCL) is based on the number of trials with one or more failures.
(5) The calculated total leak rate reflects the upper 95% quantile value at an upper 95% confidence bound.
(6) KNPP allowable leakrate is 3.69 gpm. 1 gpm is reserved for the large number of inservice HEJ sleeves

6.0 References

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

6.2 Safety Evaluation Report (SER), "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 126 to Facility Operating License No. DPR-43, Wisconsin Public Service Corporation, et. Al., Kewaunee Nuclear Power Plant, Docket No. 50-305," J. Tsao, United States Nuclear Regulatory Commission, September 1996.

6.3 EPRI Report NP 7480-L, Addendum 3, 1999 Database Update, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate Repair Limits," Electric Power Research Institute, May 1999.

6.4 FTI Document 32-5008906-00, Kewaunee Voltage-Based ARC Calculations (April 2000 Outage).

6.5 NRC Letter to NEI, dated March 18, 1996, Probe Wear Criteria.

6.6 FTI Document 51-5008538-00, ARC Probe Wear Monitoring for Kewaunee April 2000 ET Inspection.

6.7 WCAP 14277, Revision 1, SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections, December 1996.

6.8 FTI Document 51-5001160-01, Steam Generator POB – Simulation Code – POB97vb.F90, March 2000.

6.9 FTI Document 51-5001151-00, Steam Generator Leak Rate – Simulation Code – LKR97vb.F90, March 1998.

6.10 NEI Letter to the NRC, Updated ODSCC ARC Correlations for 7/8-inch Diameter Tubes, dated December 29, 1997

6.11 EPRI Report NP 7480-L, Addendum 2, 1998 Database Update, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate Repair Limits," Electric Power Research Institute, April 1998.

6.12 FTI Document 86-5003283-00, "Kewaunee Steam Generator 90 Day Report for Voltage-Based Repair Criteria", January 1999.