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U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION (CPSES)-UNIT 1
DOCKET NOS. 50-445
SUBMITTAL OF UNIT 1 SEVENTH REFUELING OUTAGE (1RF07)
GL 95-05 REPORT

REF: TXU letter logged TXX-00036 from C. L. Terry to the NRC dated February 4, 2000

Via the above referenced letter TXU Electric submitted the 90-day report pursuant to the guidance of Attachment 1 to the Generic Letter (GL) 95-05 "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking".

TXU Electric noted that the section 3 of the report titled, "Comanche Peak Unit-1 2000 Pulled Tube Data for TSP Locations", was not available at that time. TXU Electric has subsequently received the information to complete section 3. The remainder of the report and associated tables are unchanged from the referenced letter. The enclosed report is provided in accordance with the guidance by GL 95-05.

A001

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This communication contains no new licensing basis commitments regarding CPSES Unit 1. If you have any questions, please contact Mr. Obaid Bhatty at (254) 897-5839.

Sincerely,

C. L. Terry

By: Roger D. Walker
Regulatory Affairs Manager

OAB/oab
Enclosure

cc: E. W. Merschoff, Region IV
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Resident Inspectors, CPSES

ENCLOSURE TO TXX-00055

COMANCHE PEAK UNIT - 1

CYCLE 8 VOLTAGE-BASED REPAIR CRITERIA REPORT

February 2000

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Comanche Peak Unit - 1

Cycle 8 Voltage-Based Repair Criteria Report

1.0 Introduction

This report provides a summary of the Comanche Peak Unit-1 steam generator (SG) bobbin and rotating pancake coil (RPC) probe inspection at tube support plate (TSP) intersections, together with leak rate and tube burst probability analysis results for a postulated steam line break (SLB) accident. The results support implementation of the voltage-based repair criteria as outlined in the NRC Generic Letter 95-05 (Reference 9-1). A 1.0-volt repair criterion for outside diameter stress corrosion cracking (ODSCC) indications at the TSP intersections has been approved for implementation starting with the current cycle (Cycle 8, Reference 9-2). Information requested by the Generic Letter to support a 1-volt repair criterionis provided in this report.

A relatively small number of ODSCC indications were detected during the EOC-7 inspection (a total of 104 indications from all 4 SGs combined), and a majority of those indications (65) was found in SG-4. Therefore, leak and burst analysis based on the actual bobbin voltage distribution (condition monitoring analysis) was carried only for SG-4 as it clearly bounds the other 3 SGs. Westinghouse generic methodology based on Monte Carlo simulations presented in Reference 9-3 was used, and this methodology has been utilized for all leak and burst analyses performed todate by the industry in support of Generic Letter 95-05.

Analyses were also performed to project leak rates and tube burst probabilities for a postulated SLB condition at the end of the ongoing cycle (Cycle 8) applying the 1.0 volt repair criteria. Because of the relatively small indication population detected during the recent (EOC-7) inspection, adequate data is not yet available to define a reliable growth distribution for Comanche Peak Unit-1. Therefore, a bounding growth distribution based on growth data for ¾" tube plants during cycles that utilized a 1-volt repair criterion was applied for the EOC-8 projections.

Two tube segments (R31C81 and R25C81) in SG-4 each with 2 TSP intersections were pulled during this inspection for detailed laboratory examination. Results from leak and burst tests and metallurgical examination are presented in Section 3. Eddy current and repair data for EOC-7 TSP indications are provided in Section 4. The leak and burst database applied and the Monte Carlo analysis used to estimate leak rate and tube burst probabilities are briefly described in Sections 5 and 6. The EOC-8 voltage distributions projected using the bounding growth distribution are presented in Section 7. Leak rates and burst probabilities for the actual EOC-7 voltage distributions and projected EOC-8 voltage distributions are reported in Section 8 and compared with allowable limits.

2.0 Summary and Conclusions

Only a total of 104 indications were found in the EOC-7 inspection, a majority of which (65) was in SG-4. All indications detected were on the hot leg side. Only one indication over 1 volt was detected in all 4 SGs combined. It was found in SG-4 and was inspected with a RPC probe. The indication was confirmed as a flaw, and the tube containing it was pulled for detailed laboratory examination. No ID or circumferential indications at the TSP intersections or indications extending outside the TSP were found in this inspection. Only one mixed residual signal at a TSP intersection that could potentially mask a 1.0 volt bobbin indication (residual signal voltage 1.5 volts or greater) was detected in this inspection (in SG-3); it was inspected with a RPC probe and no degradation was detected.

SLB leak rate and tube burst probability analyses were performed for the actual EOC-7 bobbin voltage distributions as well as the projected EOC-8 bobbin voltage distributions. Since about 63% of the combined EOC-7 TSP ODSCC population from all 4 SGs (65 out of a total of 104) was found in SG-4, the leak and burst analysis results based on the actual bobbin voltage distribution for SG-4 should bound those for the other 3 SGs. Therefore, condition monitoring analysis was carried only for SG-4. The limiting SLB leak rate (1.4×10^{-4}) and tube burst probability (1.2×10^{-5}) values obtained using the actual measured EOC-7 voltages for SG-4 are relatively small, and they are 3 to 5 orders of magnitude below the corresponding acceptance limits (27.79 gpm at room temperature and 10^{2}).

The leak rate and tube burst probability projections at the EOC conditions for the current cycle (Cycle 8) are also well within their acceptable limits. The limiting EOC-8 SLB leak rate projected using the standard analysis methodology (Reference 9-3) and a constant POD of 0.6 is 0.14 gpm. This value is predicted for SG-4, which had the largest number of indications among the 4 SGs in the EOC-7 inspection. Because the ODSCC indication population observed thus far in Comanche Peak Unit-1 SGs is relatively small, a meaningful plant-specific growth distribution is not yet available. Therefore, in accordance with GL 95-05 a bounding growth distribution based on growth data for ¾" tube plants during cycles that utilized a 1-volt repair criterion was applied. The bounding growth distribution utilized is very conservative, and the actual growth during Cycle 8 is expected to be substantially below the bounding distribution applied. Even with this conservative growth distribution, the limiting EOC-8 leak rate projected (0.14 gpm, in SG-4) is more than 2 orders of magnitude below the allowable EOC-8 leakage limit of 27.79 gpm (room temperature). The corresponding tube burst probability, 1.9×10^{-3}, is about $1/5^{th}$ of the NRC reporting guideline of 10^{-2}. Thus, the GL 95-05 requirements for continued plant operation for the projected duration of Cycle 8 are met.

The results of the non-destructive examination, leak and burst testing, and destructive examination of the TSP regions in 2 tube segments pulled during the EOC-7 inspection are summarized in this report. These TSP crevice regions had OD axially oriented intergranular corrosion and the corrosion was confined to the TSP intersection. The intergranular corrosion present is typical of that in the EPRI database gathered in support of voltage-based repair criteria. Data from leak and burst tests are compared to the EPRI database for 3/4" outside diameter steam generator tubes, and the effect of including the new test data in the reference database is evaluated. The review of the data indicates that the correlations of the burst pressure, probability of leak and leak rate to the common logarithm of the bobbin amplitude are not substantially changed by the inclusion of the new data.

3.0 Comanche Peak Unit-1 1999 Pulled Tube Data for TSP Locations

3.1. Comanche Peak Unit-1 Pulled Tube Examination Results

3.1.1. Introduction

Two tube segments removed from Comanche Peak Unit 1 steam generator 4 (R31C81 and R25C81) were examined at the Westinghouse Science and Technology Center in support of implementation of the voltage-based repair criteria per Generic Letter 95-05. The following TSP regions on the hot leg side in both tubes were examined: flow distribution baffle (FDB), and first hot leg tube support plate (TSP-H3) and second hot leg tube support plate (TSP-H5). Prior to tube removal, field eddy current inspection showed potential indications (PI) by the bobbin probe at both TSPs 3 and 5 of Tube R31C81 and at TSP-H5 of Tube R25C81. Field NDE in the FDB regions of tubes both and TSP-H3 location of Tube R25C81 found no degradation. Field +Point inspection showed a single axial indication (SAI) at the TSP-H3 location of Tube R25C81 only, and no degradation was detected at the other TSP locations indicated above.

Nondestructive laboratory examinations were performed by visual, eddy current, ultrasonic testing and radiographic examinations. Subsequently, dimensional characterization and room temperature leak and burst testing were performed on all specimens. Burst tests were performed on the TSP-H3 and TSP-H5 segments of both tubes as well as control specimens from the free span region of the tubes. In addition, tensile tests were also conducted on samples from the free span sections of the tubes. Following burst testing, the specimens were examined using SEM fractography and metallographic techniques to characterize the fracture surfaces and to determine the extent to which corrosion was present.

3.1.2 Nondestructive Examinations

The tube sections were inspected in the laboratory using eddy current techniques similar to those used during the field inspection. These inspections utilized a 0.610-inch diameter differential bobbin coil probe, and a Zetec +Point probe. The data were collected using a R/D Tech TC 6700 and recorded on optical disks. Analysis of the data was conducted using the Westinghouse ANSER system.

A review of the field eddy current data for the TSP-H3 and TSP-H5 locations in tube R25C81 and R31C81 yielded qualitatively similar results to the original field analyses. Additional small amplitude indications were, however, identified in the bobbin signal for the TSP-H3 location of tube R25C81 and in the +Point data for the TSP-H3 and TSP-H5 locations of tube R31C81. No degradation was detected at the FDB locations of both tubes in the field data as well as in the laboratory data. No destructive examination was performed for the FDB intersections.

Table 3-1 summarizes the eddy current results for the areas of interest. The +Point results shown are from the 300kHz channel and the bobbin coil results are from the 550/130 kHz MIX channel. The laboratory review of the field bobbin coil signals for the TSP-H3 and TSP-H5 locations are in qualitative agreement with the field results with the exception of a 0.36 volt signal found at TSP-H3 of Tube R25C81 in the laboratory review (which was called NDD in the field). The laboratory data from the bobbin coil for Tube R31C81 were distorted by tube noise so that quantitative comparison with the field data was not possible. The laboratory results for tube R25C81 showed a slight increase in voltage for the bobbin response at the TSP-H5 location (1.35 versus 1.19 volts), but this increase is negligible and likely due to tube pulling effects. The laboratory +Point probe results for the TSP locations of R31C81 and R25C81 identified indications at both TSP-H3 and TSP-H5 locations of Tube R31C81 and at TSP-H5 of Tube R25C81. These results are consistent with the laboratory review of the field data.

After completing the eddy current inspections, ultrasonic and X-ray radiographic examinations of the tube sections were conducted. Review of the laboratory ultrasonic data indicated the presence of indications at both TSP-H3 and TSP-H5 locations of R31C81 and R25C81. These indications are axially oriented, with the TSP-H5 region of R25C81 showing the greatest extent (axially and circumferentially) of all the tube support plate locations. The circumferential extents reported for the UT results in Table 3-1 represent the angular range of axial indications in the UT data.

3.1.3 Leak, Burst and Tensile Data

Following NDE testing, room temperature leak testing was performed on all specimens at three pressures: normal operating pressure 1500 psi, steam line break conditions 2560 psi, and an intermediate pressure 2250 psi. Tube extensions were welded to each end of the specimen to provide a corrosion-free surface to assure leak-free attachment of Swagelok fittings. No leaks were detected on any of the specimens.

After leak testing, the TSP-H3 and TSP-H5 sections of Tubes R25C81 and R31C81 were burst tested at room temperature using the Westinghouse standard burst testing procedure. A bladder and lubricated foil reinforcement were used. In addition to the TSP regions, control free span (FS) sections of each tube without NDE indications were also burst tested. All of the burst openings were axially oriented. Figures 3-1 through 3-4 provide sketches of the burst openings and of the secondary corrosion observed on the four TSP specimens. Table 3-2 presents a summary of the burst data. All burst pressures are well above the burst margin guidelines of the draft R.G. 1.121. Free span burst pressures varied little for the two tubes with values of 10,600 and 10,700 psig. The burst pressures for the tube support plate locations (TSPs H3 and H5) ranged from 9,169 to 10,400 psig. Table 3-2 also includes room temperature tensile test data obtained on additional FS sections from both tubes. The tensile properties appear typical of MA Alloy 600 steam generator tubing of this vintage.

Examination with the scanning electron microscope of the TSP-H3 burst from tube R25C81 revealed the presence of intergranular corrosion (SCC) on the OD surface of the tube, thus confirming the field bobbin reevaluation at this location, see Table 3-1. The corrosion observed on the TSP regions was entirely confined to the TSP crevice region.

3.1.4 Destructive Examinations

SEM fractography was performed at all fracture locations for the TSP specimens of tubes R25C81 and R31C81 after the specimens were burst tested. Tables 3-3 through 3-6 contain the length and depth (relative to the wall thickness) measurements as well as ligament areas for the bursts at TSP-H3 and TSP-H5 for tubes R25C81 and R31C81, respectively.

Each axial burst fracture faces had OD origin intergranular corrosion that occurred as a macrocrack composed of a number of OD intergranular microcracks joined together by ligaments. Most of these ligaments had only or mostly intergranular features, indicating that these particular ligaments grew together during plant operation. Each of the four burst corrosion macrocracks also had ligaments with predominantly ductile features, indicating that these particular ligaments formed (tore) during either tube pulling, leak testing, burst testing, or subsequent laboratory handling.

The longest corrosion macrocrack was the crack network for the TSP-H5 region of Tube R31C81. It was 0.485 inch long, averaged 24% deep and had a maximum depth of 41%. The TSP-H3 region of Tube R31C81 was 0.380 inch long, averaged 20.3% deep and had a maximum depth of 56%. The TSP-H5 region of Tube R25C81 was 0.240 inch long, had a maximum depth of 49% throughwall and averaged 36% throughwall. The TSP-H3 region of Tube R25C81 was 0.123 inch long averaged 19.7% deep and had a maximum depth of 44%.

In addition to visual examination of the burst areas of TSP-H3 and TSP-H5 of tubes R31C81 and R25C81, transverse and radial metallographic analyses were performed on the specimens. The data are shown in Table 3-7. Shallow cellular corrosion comprised of short axial and oblique cracks was identified by the radial grinds, with the oblique cracks being less than 30% deep.

Based on the appearance of the cracks examined by SEM, the corrosion morphology was composed primarily of axial intergranular stress corrosion cracking (IGSCC) with some shallow intergranular cellular corrosion (ICC) also present. ICC is a crack structure composed of a mixture of axial, circumferential and oblique angled IGSCC. The OD intergranular corrosion present is typical of that in the EPRI database gathered in support of voltage-based repair criteria.

3.1.5 Summary

The TSP crevice regions of Tubes R25C81 and R31C81 had OD intergranular corrosion. The FDB (TSP-H1) regions did not have corrosion. Laboratory NDE examinations confirmed the field inspection data; however, additional small amplitude indications were identified in the bobbin signal for the TSP-H3 location of tube R25C81 and in the +Point data for the TSP-H3 and TSP-H5 locations of tube R31C81. No leakage was observed for any of the specimens for pressures up to the steam line break value 2560 psig. Burst testing showed that the corroded TSP regions all had strength properties exceeding the draft R.G. 1.121 guidelines. All burst opening were axial.

3.2 Comanche Peak Unit-1 Pulled Tube Evaluation for Voltage Based Repair Criteria Applications

The pulled tube examination results were evaluated for application to the EPRI database for voltage based repair criteria applications. The eddy current data were reviewed, including reevaluation of the field data, to finalize the voltages assigned to the indications and to assess the field NDD calls for detectability under laboratory conditions. The data for incorporation into the EPRI database were then defined and reviewed against the EPRI data exclusion criteria to provide acceptability for the database.

3.2.1 Eddy Current Data Review

Table 3-8 provides a summary of the eddy current data evaluations for the Comanche Peak-1 pulled tubes. These NDE data results have been discussed in the above Section 3.1.2. The reevaluation of the field bobbin data shows an indication at TSP-H3 of R25C81 and differs in magnitude for the R31C81 TSP-H3 indication. The bobbin reevaluation for R25C81 TSP-H3 is shown in Figure 3-5. The signal shows a 0.35 volt (0.36 corrected to laboratory standard) signal with zero percent depth. The signal was likely not called in the field inspection due to the zero percent depth and some distortion of the signal. The reevaluation is appropriate for consideration of the indication in the EPRI database. The reevaluation of the bobbin voltage for R31C81 TSP-H3 is shown in Figure 3-6. The highly distorted signal shows two potential flaw components separated by a noise signal such as from probe rattle. A voltage of 0.3 volt is assigned to this indication to reflect the two flaw components. The field evaluation conservatively assigned 0.57 volt to the indication, which encompasses the flaw and noise response. The lower 0.3 volt response for the flaw only is the more appropriate voltage for consideration in the EPRI database. The reevaluated field bobbin voltages, including the adjustment for cross calibration of the field ASME standard to the laboratory standard, are used for the EPRI leak and burst database. The reevaluation was performed by the same analyst that performed a large part of the EPRI pulled tube database and the use of these voltages minimizes analyst variability in the database, which is separately accounted for in voltage based repair criteria applications as an NDE uncertainty.

The post-pull laboratory inspection results show no significant changes in the bobbin or RPC voltages. This result indicates negligible damage to the TSP indications as a result of the tube removal operations.

3.2.2 Comanche Peak Unit-1 Data for Voltage Based Repair Criteria Applications

The pulled tube leak test, burst test and destructive examination results are summarized in Table 3-9. No leakage was found in room temperature leak tests of the TSP indications up to the SLB pressure differential of 2560 psi.

The Comanche Peak-1 pulled tube results were evaluated against the EPRI data exclusion criteria for potential exclusions from the database. Criteria 1a to 1e apply primarily to unacceptable voltage, burst or leak rate measurements and indications without leak test measurements. The indications have very high burst pressures for their voltage magnitudes and the burst pressures tend to be higher for the higher voltage indications. Calculations of the burst pressures from the destructive exam profiles indicate burst pressures of 8560 to 8700 psi for R25C81 TSP-H5 and R31C81 TSP-H5 compared to the measured values of 10000 and 9877 psi, respectively. Typically, these calculations agree with the measured burst pressures within a few hundred psi. Based on these observations, the burst test data were reviewed but the testing was found to correctly follow procedures with no identifiable errors in the measurements or recording of the results. Therefore, Criteria 1a to 1e are not applicable to the Comanche Peak-1 indications. Criterion 3 applies to potential errors in the leakage measurements and is not applicable to the Comanche Peak-1 indications since there are no known errors in the measurements and no leakage was found for the indications.

EPRI Criterion 2a applies to atypical ligament morphology for indications having high burst pressures relative to the burst/voltage correlation and states that high burst pressure indications with ≤ 2 uncorroded ligaments in shallow cracks < 60% deep shall be excluded from the database. Table 3-9 identifies the number of remaining ligaments and the maximum depths for the indications. Three indications have maximum depths < 60% but have more than 2 ligaments and Criterion 2a is not applicable. However, the R25C81, TSP-H3 indication has a 44% maximum depth with 2 ligaments and a high burst pressure. Therefore, this indication satisfies Criterion 2a and is excluded from the EPRI leak and burst database. The burst pressure for R25C81 TSP-H5 is particularly high (above upper 95% confidence on the burst correlation) but has more than 2 ligaments and cannot be excluded from the database.

As shown in the last column of Table 3-9, the TSP-H3 indication of R25C81 is to be excluded from the EPRI database and not included in the probability of leakage and burst correlations. The indications at R25C81 TSP-H5 and R31C81, TSPs-H3 and H5 are included in the burst and probability of leakage correlations. The impact of the indications on the leak and burst correlations is further discussed in the section below.

3.3 Comparison of Comanche Peak Unit-1 Data with EPRI Database

This section provides evaluations of the results obtained from leak rate and burst testing of the TSP-H3 and TSP-H5 regions of Tubes R25C81 and R31C81 removed from Comanche Peak Unit-1 SGs. The results of the destructive examination of the tube are discussed in Section 3.1. The data germane to the leak and burst correlations for voltage-based repair criteria applications are given in Table 3-8. The results of the destructive examinations, e.g., leak and burst tests, are compared to the database of similar test results for ¾" outside diameter steam generator tubes. In addition, the effect of including the new test data in the latest database available for ¾" tubes (Addendum-H3 database documented in Reference 9-6) was evaluated. In summary, the test data are consistent with the database relative to the burst pressures and the probability of leak as a function of the bobbin amplitude. The leak rate correlation as function of bobbin amplitude was not affected, as no new leakage data is available from this pulled tube examination.

3.3.1 Suitability for Inclusion in the Database

The reported information on the destructive examinations of the R25C81 and R31C81 tube sections was reviewed in Section 3.2 relative to the EPRI guidelines for inclusion/exclusion of tube specimen data in the leak and burst database. This review revealed that data for one of the TSP segments (TSP-H3 in Tube R25C81) should be excluded from the reference database. Therefore, only the leak and burst test results for the remaining 3 TSP segments were added to the database. The resulting correlations should be considered applicable to the use ofvoltage-based repair criteria for indications in ¾" diameter tubes in Westinghouse SGs.

3.3.2 Burst Pressure

The burst test results for the three TSP locations, with a non-zero bobbin amplitudes, that did not meet the EPRI exclusion criteria were considered for evaluation. These burst pressures are plotted on Figures 3-7 and 3-8 together with the data from the EPRI Addendum 3 database (Reference 9-6).

1. A visual examination of the data relative to the Addendum 3 database indicates that two of the measured burst pressures fall within the scatter band of the reference data. The third appears to have a higher burst pressure than would be expected by inspection. Figure 3-7 shows that one of the burst pressures corresponds to the regression mean prediction line, the second is on the upper 95% confidence, two-sided tolerance bound for a 90% portion of the underlying population (5% in each tail), and the third is about 1000 psi above the upper tolerance bound.

2. There are too few additional data to suggest some sort of significant statistical anomaly relative to the existing database.

In summary, the visual examination of the data does not indicate that any significant departures from the reference database should be strongly suspected.

Since the burst pressure data from the Comanche Peak Unit-1 tube specimens were not indicated to be from a separate population from the reference data, the regression analysis of the burst pressure on the common logarithm of the bobbin amplitude was repeated with the additional data included. A comparison of the regression results obtained by including these data in the regression analysis is provided in Table 3-10. Regression predictions obtained by including these data in the regression analysis are also shown on Figure 3-8. A summary of the changes is as follows:

1) The intercept of the burst pressure, P_B, as a linear function of the common logarithm of the bobbin amplitude regression line is increased by 0.75%, or about 18 psi. Because of the logarithmic scale, the intercept corresponds to bobbin amplitude of 1 volt. The change has the effect of uniformly increasing the predicted burst pressure as a function of the bobbin amplitude by a miniscule amount. This change is expected because the specimen bobbin voltages are less than the mean of the database and two of the burst pressures are greater than the regression predictions.

2) The absolute slope of the regression line is increased by 1.4%, i.e., the slope is more steep. This has the effect of decreasing, albeit very slightly, the calculated burst pressure as a function of bobbin amplitude for large indications, i.e., for those indications with a log-amplitude greater than the mean log-amplitude (about 2.5 V).

3) The standard error of the residuals is increased by 4.1%. This would be expected to more than offset the effect of the changes in the intercept and slope and lead to a reduction in the lower 95th percentile prediction values for significant voltage levels, say, above 1 V.

The net effect of the changes on the $1.43 \times \Delta_{SLB}$ structural limit, using 95%/95% lower tolerance limit material properties, is to decrease it by 0.11 V, i.e., from 4.70 to 4.59 V. For a SLB differential pressure of 2405 psi, the structural limit decreases from 5.69 to 5.54 V. This results from the increase in the standard error of the regression predictions. Based on the relatively small change in the structural limit, the change in the probability of burst (PoB) would also be expected to be small. The effects of the changes on the PoB are illustrated on Figure 3-9. As expected the PoB is slightly increased for the entire range of possible amplitudes.

3.3.3 Probability of Leak

The data of Table 3-8 were examined relative to the Addendum 3 correlation for the probability of leak (PoL) as a function of the common logarithm of the bobbin amplitude. Figure 3-10 illustrates the Comanche Peak Unit-1 data relative to the reference correlation. All of the specimens exhibited expected leak behavior relative to the predicted probabilities of leak, i.e., the indications had calculated low probabilities of leak and did not leak. The largest of the three had an expected PoL of about 0.02. The test results are not statistically different from the expectations. Based on the examination of the data, there is no significant evidence of irregular results, i.e., outlying behavior is not indicated.

In order to assess the quantitative effect of the new data on the correlation curve, the database was expanded to include the Comanche Peak Unit-1 data points and a *Generalized Linear Model* regression of the PoL on the common logarithm of the bobbin amplitude was repeated. A comparison of the correlation parameters with those for the reference database is shown in Table 3-11. These results indicate:

1) An 0.4% decrease in the *logistic* intercept parameter from -4.81 to -4.83.

2) A 0.3% increase in the *logistic* slope parameter from 8.42 to 8.45.

3) The absolute values of the variance and covariance of the parameters changed by less than 1%. Examination of Figure 3-10 indicates that the probability of leak for all voltages is not meaningfully changed by the inclusion of the Comanche Peak Unit-1 data. The PoL equation generally has a small effect on the total estimated leak rate and it would be expected that there would be no significant impact on the 95% confidence bound on the total estimated leak rate from a single SG.

4) The deviance of the regression errors increased by 0.1%. An increase is expected when additional data is added because the deviance is akin to the sum of squares of the errors. The Pearson standard error decreased by 0.6% from 0.97 to 0.96 indicating no significant change in the model's predictions.

In order to further examine the changes to the PoL, the ratio of the new to reference correlation was plotted on Figure 3-11. Examination of the figure indicates an decrease in the PoL for all indications up to about 4 V. However, the ratio is not really significant. So, the effect of the changes in the parameter values and variances would be expected to be small relative to the calculation of the 95% confidence bound of the total leak rate from a SG.

3.3.4 Free Span SLB Leak Rate vs. Bobbin Voltage Amplitude

As previously noted, none of the removed tube specimens exhibited leakage under SLB conditions. Therefore there were no changes to the leak rate correlations from those presented in Reference 9-6.

3.3.5 Conclusions

The review of the effect of the Comanche Peak Unit-1 data indicates that the correlations of the burst pressure and the probability of leak to the common logarithm of the bobbin amplitude are not substantially changed by the inclusion of the data. It is judged that the conclusions relative to EOC probability of burst and EOC total leak rate based on the use of the reference database would not be significantly changed relative to results obtained from correlations developed after adding the Comanche Peak Unit-1 data to the Addendum 3 database.

The database correlations were not significantly affected by the addition of new data for 3/4" nominal diameter, Alloy 600 MA, SG tubes. Thus, the results of condition monitoring and operational assessment evaluations would not be expected to be changed significantly by the inclusion of the Comanche Peak Unit-1 data.

Table 3-1.
Summary of NDE Data for Comanche Peak Unit-1 Tubes

Tube	Location	Field Eddy Current		Field Data Review		Lab. Eddy Current		X-Ray	Lab UT
		Bobbin Coil[1] Volts	+Point 300 kHz Volts/l (in.)	Bobbin Coil[1] Volts	+Point 300 kHz Volts	Bobbin Coil Volts/%	+Point 300 kHz Volts/%/l (in.)		
R31C81	FDB	NDD	NDD	NDD	NDD	NDD	NDD	N/A	N/A
	TSP-H3	0.57 V	NDD	0.30 V	PI 0.12 V	DI	0.11V/51%/0.39 in. Circ. Extent 107 deg.	NDD	MAI
	TSP-H5	0.74 V	NDD	0.69 V	PI 0.19 V	DI 0.55 V	0.26V/27%/0.36 in. Circ. Extent110 deg.	NDD	MAI
R25C81	FDB	NDD	NDD	NDD	NDD	NDD	NDD	N/A	N/A
	TSP-H3	NDD	NDD	0.36V	NDD	NDD	NDD	NDD	MAI
	TSP-H5	1.17 V	SAI 0.64V/0.2 in.	DSI. 1.19 V	0.27V	1.35 V	0.41 V/38%/0.3 in. Circ. Extent 116 deg.	NDD	MAI
R7C84	FDB	NDD	NDD	NDD	NDD	NDD	NDD	N/A	N/A
R22C89	FDB	NDD	NDD	NDD	NDD	NDD	NDD	N/A	N/A

1. Bobbin voltages include cross calibration to ARC preference calibration standard.

NDD - No Detectable Degradation
N/A - Not Applicable
SAI - Single Axial Indication
DI - Distorted Indication
PI - Possible Indication
MAI - Multiple Axial Indication

Table 3-2.
Room Temperature Burst and Tensile Test Data for Comanche Peak Unit 1 SG Tubes

Location	Burst Pressure, (psig)	Burst Length, (Inches)	Burst Width, (Inches)	Tensile Test Ultimate Load (lbs.)	0.2% Offset Yield Strength,	Tensile Strength,	Tensile Elongation
Tube R31C81							
Free Span	10700	1.6636	0.3555	9500	49	100	54.0%
TSP H3	9169[2]	1.5176	0.5305				
TSP H5	9877	1. 1123	0.3395				
Tube R25C81							
Free Span	10600	1.6659	0.3846	9600	49	100	53.8%
TSP H3	10400	1.3131	0.4007				
TSP H5	10000	1.4271	0.5121				

[1]Leakage occurred at 9130 psig

Table 3-3.
SEM Fractographic Data for Intergranular Macrocracks, Tube R25C81, TSP-H3 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
0.0/00	Crack bottom located 0.237 inches above TSP bottom.
(0.003/11)	
(0.008/13)	
(0.009/00) Ligament 1	Ligament 1: Area = 0.16, Minor Axis @ 90°, Major Axis @ 15°
(0.013/32)	
(0.018/40)	
(0.023/41)	
(0.028/44)	
(0.033/00) Ligament 2	Ligament 2: Area = 0.49, Minor Axis @ 60°, Major Axis @ 15°
(0.034/41)	
(0.038/11)	
(0.043/31)	
(0.048/28)	
(0.053/26)	
(0.058/23)	
(0.063/18)	
(0.068/18)	
(0.073/14)	
(0.078/14)	
(0.083/14)	
(0.088/17)	
(0.093/18)	
(0.098/3)	
(0.103/6)	
(0.108/0)	
(0.113/12)	
(0.118/14)	
(0.123/0)	Crack Top at 0.360 inches above TSP bottom.

a -Area=inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees

Table 3-4
SEM Fractographic Data for Intergranular Macrocracks
Tube R25C81 – TSP-H5 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
0.0/00	Crack bottom located 0.360 inches above TSP bottom.
(0.005/18)	
(0.010/27)	
(0.015/31)	
(0.020/33)	
(0.024/00)	Ligament 1: Area = 0.92, Minor Axis @ 90°, Major Axis @ 0°
(0.025/33)	
(0.030/26)	
(0.035/29)	
(0.040/42)	
(0.045/44)	
(0.050/44)	
(0.055/42)	
(0.060/42)	
(0.065/49)	
(0.070/49)	
(0.075/46)	
(0.080/42)	
(0.085/00)	Ligament 2: Area = 0.54, Minor Axis @ 90°, Major Axis @ 0°
(0.090/42)	
(0.095/48)	
(0.100/48)	
(0.105/48)	
(0.110/49)	
(0.115/48)	
(0.120/46)	
(0.125/44)	
(0.130/42)	
(0.135/48)	
(0.140/48)	
(0.145/46)	
(0.150/38)	
(0.155/42)	

Table 3-4 (Continued)
SEM Fractographic Data for Intergranular Macrocracks,
Tube R25C81 – TSP-H5 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
(0.160/40)	
(0.165/37)	
(0.169/00)	Ligament 3: Area = 0.24, Minor Axis @ 90°, Major Axis @ 30°
(0.170/33)	
(0.175/22)	
(0.180/27)	
(0.185/26)	
(0.190/29)	
(0.195/33)	
(0.200/33)	
(0.205/31)	
(0.210/26)	
(0.215/27)	
(0.220/27)	
(0.225/27)	
(0.226/00)	Ligament 4: Area = 0.56, Minor Axis @ 90°, Major Axis @ 15°
(0.230/26)	
(0.235/13)	
(0.240/00)	Crack Top at 0.600 inches above TSP bottom.

a - Area=inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees

Table 3-5
SEM Fractographic Data for Intergranular Macrocracks,
Tube R31C81 – TSP-H3 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
(0.0/00)	Crack bottom located 0.070 inches above TSP bottom.
(0.005/26)	
(0.010/10)	
(0.015/11)	
(0.020/11)	
(0.025/33)	
(0.030/26)	
(0.035/29)	
(0.040/25)	
(0.045/00)	Ligament 1: Area = 1.00, Minor Axis @ 60°, Major Axis @ 15°
(0.046/43)	
(0.050/50)	
(0.055/56)	
(0.060/55)	
(0.070/54)	
(0.075/32)	
(0.080/41)	
(0.085/41)	
(0.090/45)	
(0.095/49)	
(0.100/53)	
(0.105/52)	
(0.110/49)	
(0.115/48)	
(0.120/46)	
(0.125/43)	
(0.130/21)	
(0.133/00)	Ligament 2: Area = 1.90, Minor Axis @ 60°, Major Axis @ 15°
(0.135/00)	
(0.140/00)	
(0.145/07)	
(0.150/16)	
(0.155/31)	
(0.160/29)	
(0.165/25)	
(0.170/11)	
(0.175/08)	

Table 3-5 (Continued).
SEM Fractographic Data for Intergranular Macrocracks
Tube R31C81 – TSP-H3 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
(0.180/05)	
(0.184/00)	Ligament 3: Area = 0.27, Minor Axis @ 90°, Major Axis @ 0°
(0.185/00)	
(0.190/14)	
(0.193/00)	Ligament 4: Area = 0.40, Minor Axis @ 90°, Major Axis @ 0°
(0.195/18)	
(0.200/16)	
(0.205/00)	
(0.210/00)	
(0.215/00)	
(0.220/09)	
(0.225/18)	
(0.230/25)	
(0.235/27)	
(0.240/00)	Ligament 5: Area = 0.36, Minor Axis @ 90°, Major Axis @ 0°
(0.245/23)	
(0.250/18)	
(0.255/07)	
(0.260/07)	
(0.265/07)	
(0.270/14)	
(0.275/16)	
(0.280/17)	
(0.283/00)	Ligament 6: Area = 0.33, Minor Axis @ 90°, Major Axis @ 0°
(0.285/16)	
(0.290/14)	
(0.295/02)	
(0.300/03)	
(0.305/06)	
(0.309/00)	Ligament 7: Area = 0.93, Minor Axis @ 90°, Major Axis @ 15°
(0.310/29)	
(0.315/29)	

a - Area=inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees

Table 3-5 (Continued)
SEM Fractographic Data for Intergranular Macrocracks,
Tube R31C81 – TSP-H3 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
(0.320/21)	
(0.325/21)	
(0.330/21)	
(0.334/00)	Ligament 8: Area = 1.21, Minor Axis @ 90°, Major Axis @ 0°
(0.335/16)	
(0.340/13)	
(0.345/00)	
(0.350/00)	
(0.355/00)	
(0.360/00)	
(0.365/08)	
(0.370/14)	
(0.375/11)	
(0.380/00)	Crack Top at 0.450 inches above TSP bottom.

a - Area=inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees

Table 3-6
SEM Fractographic Data for Intergranular Macrocracks
Tube R31C81 – TSP-H5 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
0.0/00	Crack bottom located 0.140 inches above TSP bottom.
(0.005/05)	
(0.010/09)	
(0.015/05)	
(0.019/21)	Ligament 1: Area = 0. 59, Minor Axis @ 90°, Major Axis @ 0°
(0.020/00)	
(0.025/09)	
(0.030/16)	
(0.035/21)	
(0.040/23)	
(0.050/29)	Ligament 2: Area = 0.32, Minor Axis @ 90°, Major Axis @ 0°
(0.055/24)	
(0.060/16)	
(0.065/19)	
(0.070/18)	
(0.075/16)	
(0.080/14)	
(0.085/14)	
(0.090/14)	
(0.095/14)	
(0.100/00)	Ligament 3: Area = 0.96, Minor Axis @ 75°, Major Axis @ 0°
(0.105/14)	
(0.110/25)	
(0.115/17)	
(0.120/15)	
(0.125/16)	
(0.130/18)	
(0.135/25)	
(0.140/32)	
(0.145/33)	
(0.150/32)	
(0.155/32)	
(0.160/27)	
(0.165/27)	
(0.170/30)	
(0.175/33)	
(0.180/33)	

a -Area=inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees

Table 3-6 (Continued)
SEM Fractographic Data for Intergranular Macrocracks,
Tube R31C81 – TSP-H5 Burst Specimen

Length Vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
(0.185/34)	
(0.190/39)	
(0.200/39)	
(0.205/39)	
(0.210/41)	
(0.215/39)	
(0.220/39)	
(0.225/32)	
(0.230/34)	
(0.235/37)	
(0.240/39)	
(0.245/39)	
(0.250/37)	
(0.255/37)	
(0.260/34)	
(0.265/32)	
(0.270/33)	
(0.275/33)	
(0.280/32)	
(0.281/00)	Ligament 4: Area = 5.29, Minor Axis @ 60°, Major Axis @ 0°
(0.285/34)	
(0.290/32)	
(0.295/16)	
(0.300/37)	
(0.305/39)	
(0.310/35)	
(0.315/35)	
(0.320/35)	
(0.325/37)	
(0.330/34)	
(0.335/34)	
(0.340/33)	
(0.345/34)	
(0.350/37)	

a -Area=inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees

Table 3-6 (Continued)
SEM Fractographic Data for Intergranular Macrocracks,
Tube R31C81 – TSP-H5 Burst Specimen

Length vs. Depth & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data[a]
(0.355/34)	
(0.360/32)	
(0.365/31)	
(0.366/00)	Ligament 5: Area = 0.78, Minor Axis @ 90°, Major Axis @ 0°
(0.370/21)	
(0.375/21)	
(0.380/34)	
(0.385/34)	
(0.390/32)	
(0.395/23)	
(0.310/35)	
(0.400/18)	
(0.405/00)	Ligament 6: Area = 1.56, Minor Axis @ 90°, Major Axis @ 0°
(0.410/16)	
(0.415/14)	
(0.417/00)	Ligament 7: Area = 1.00, Minor Axis @ 90°, Major Axis @ 30°
(0.420/05)	
(0.425/00)	
(0.430/00)	
(0.435/00)	
(0.440/05)	
(0.445/14)	
(0.450/07)	
(0.455/02)	
(0.460/11)	
(0.465/16)	
(0.470/14)	
(0.475/14)	
(0.480/16)	
(0.485/00)	Crack Top at 0.625 inches above TSP bottom.

a -Area=inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees

TABLE 3-7
Summary of Metallographic and Visual Examinations
Performed at TSP-H3 and TSP-H5 for Tubes R25C81 and R31C81

Specimen location	Section type	# Cracks in circumferential length	Circumferential length	Cracks/ circumferential inch	Estimated # of cracks at Mid-crevice location	Depth (% through wall)	Max. depth of ICC Oblique Components (% through wall in radial section)
R25C81 Pc 3B2C Top half of TSP-H3	Radial	5	0.28 in.	18	10	60% of axial cracks are >23% through wall	100% of oblique sections are less than 28% through wall
R31C81 Pc 3B2C TSP-H3	Radial	8	0.24 in.	33	16	60% of axial cracks are >23% through wall	90% of oblique sections are less than 23% through wall
R25C81 Pc 4B2C TSP-H5	Radial	9	0.28 in.	32	18	50% of axial cracks are >23% through wall	80% of oblique sections are less than 23% through wall

All oblique crack sections are relatively short and probably would turn toward the axial direction or intersect axial cracks before extensive growth

Table 3-8

Summary of Comanche Peak-1 1999 Pulled Tube Eddy Current Results

Tube	TSP	Field Call		Lab. Reevaluation of Field Data			Post Pull Data	
		Bobbin Volts(1)	+ Point Volts	Bobbin Volts(1)	Depth	+ Point Volts	Bobbin Volts	+ Point Volts
R25C81 SG 4	H3	NDD	NDD	0.36	DI	NDD	NDD	NDD
	H5	1.17	0.64	1.19	81%	0.27	1.35	0.41
R31C81 SG 4	H3	0.57	NDD	0.30	DI	0.12	DI	0.11
	H5	0.74	NDD	0.69	89%	0.19	0.55	0.26

Notes:

1. Bobbin voltage data include cross calibration of ASME standard to the reference laboratory standard. Cross calibration normalization voltage was 2.80 volts for SG 4 tubes (Standard ADVB-033-97).

Table 3-9

Summary of Comanche Peak-1 1999 Pulled Tube Data for ARC Applications

Tube	TSP	Bobbin Data		RPC Volts	Destructive Exam Results				Leak Rate l/hr		Burst Pressure Data - ksi				
		Volts	**Depth**		**Max. Depth**	**Avg. Depth**	**Crack Length (inch)**	**No. Lig.(1)**	**N.O. 1500 psid**	**SLB 2560 psid**	**Meas. Burst Press.**	σ_y	σ_u	**Adj. Burst Press.(2)**	**ARC Corr. Use**
R25C81 SG 4	H3	0.36	DI	NDD	44%	19 %	0.123	2	0.0	0.0	10.4			9.991	None Note 3
	H5	1.19	81%	0.27	49%	35 %	0.240	4	0.0	0.0	10.0			9.607	POL, B
	FS	-	-	-	-	-	-	-	-	-	10.6	49.0	100.0	10.183	
R31C81 SG 4	H3	0.30	DI	0.12	49%	20 %	0.380	8	0.0	0.0	9.169			8.808	POL, B
	H5	0.69	89%	0.19	41%	24 %	0.485	7	0.0	0.0	9.877			9.489	POL, B
	FS	-	-	-	-	-	-	-	-	-	10.7	49.0	100.0	10.279	

Notes:
1. Number of uncorroded ligaments reported in length versus depth profile.
2. Measured burst pressure adjusted to nominal, hot flow stress of 71.57 ksi for 3/4" diameter tubing.
3. Indication excluded from use in the EPRI leak and burst database and associated correlations based on EPRI data exclusion criterion 2a.

Table 3-10
Effect of Comanche Peak Unit-1 Tube Data
on the Addendum-3 Correlations for ¾" Tubes
Burst Pressure vs. Bobbin Amplitude Correlation

$$P_B = a_0 + a_1 \log(Volts)$$

Parameter	Addendum 3 Database Value	Database with Added Data	New / Old Ratio
a_0	7.40278	7.45800	1.0075
a_1	-2.91382	-2.95399	1.0138
r^2	81.88%	81.10%	0.9905
$\square_{Error}$	0.86077	0.89631	1.0413
Mean log(V)	0.407375	0.388884	
SS log(V)	37.06576	38.33062	
N (data pairs)	96	99	
Str. Limit (2560 psi)	4.70 V	4.59 V	0.9766
Str. Limit (2405 psi)	5.69 V	5.54 V	0.9736
p Value for a_2	$6.2 \cdot 10^{-37}$	$3.6 \cdot 10^{-37}$	
Reference σ_f	71.565 ksi		

Table 3-11
Effect of Comanche Peak Unit-1 Tube Data on the Addendum-3 Correlations for ¾" Tubes
Probability of Leak Correlation

$$\Pr(Leak) = \frac{1}{1 + e^{-[b_1 + b_2 \log(Volts)]}}$$

Parameter	Addendum 3 Database Value	Database with Added Data	New / Old Ratio
Logistic Intercept, b_1	-4.80824	-4.82706	1.0039
Logistic Slope, b_2	8.42151	8.44890	1.0033
V_{11} (1)	1.17118	1.16216	0.9923
V_{12}	-1.72177	-1.70918	0.9927
V_{22}	2.89170	2.87522	0.9943
No. of Data, N	123	126	
Deviance	45.90	45.90	
MSE	0.379	0.370	0.976
Pearson SD	0.970	0.960	0.994

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

Figure 3-1
Sketch of Burst Opening – Tube R25C81 – TSP-H3 Location

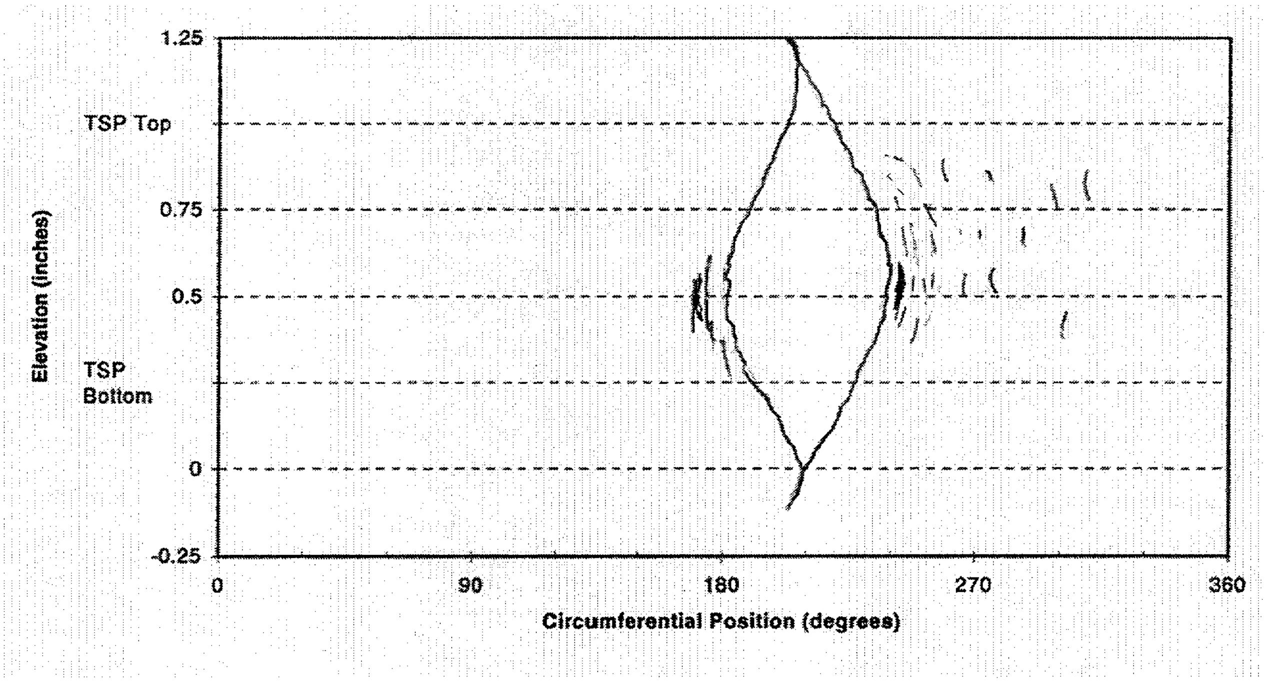


Figure 3-2.
Sketch of Burst Opening – Tube R25C81 – TSP-H5 Location

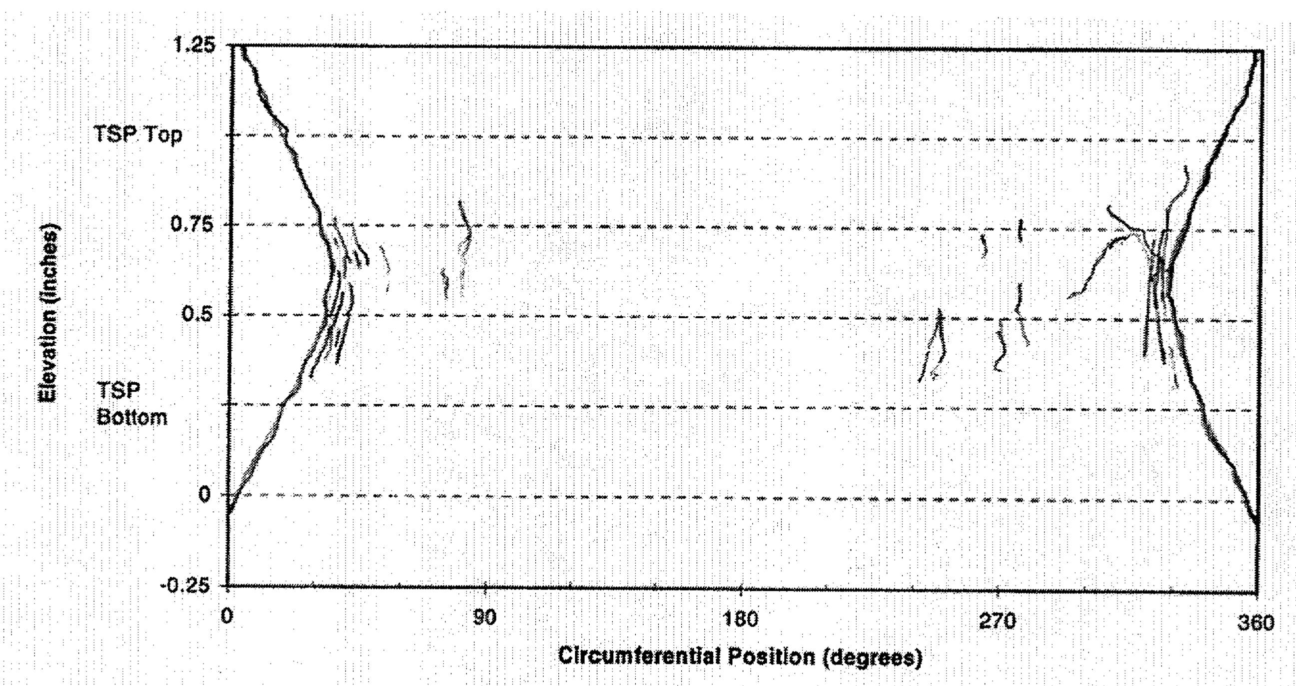


Figure 3-3
Sketch of Burst Opening – Tube R31C81 – TSP-H3 Location

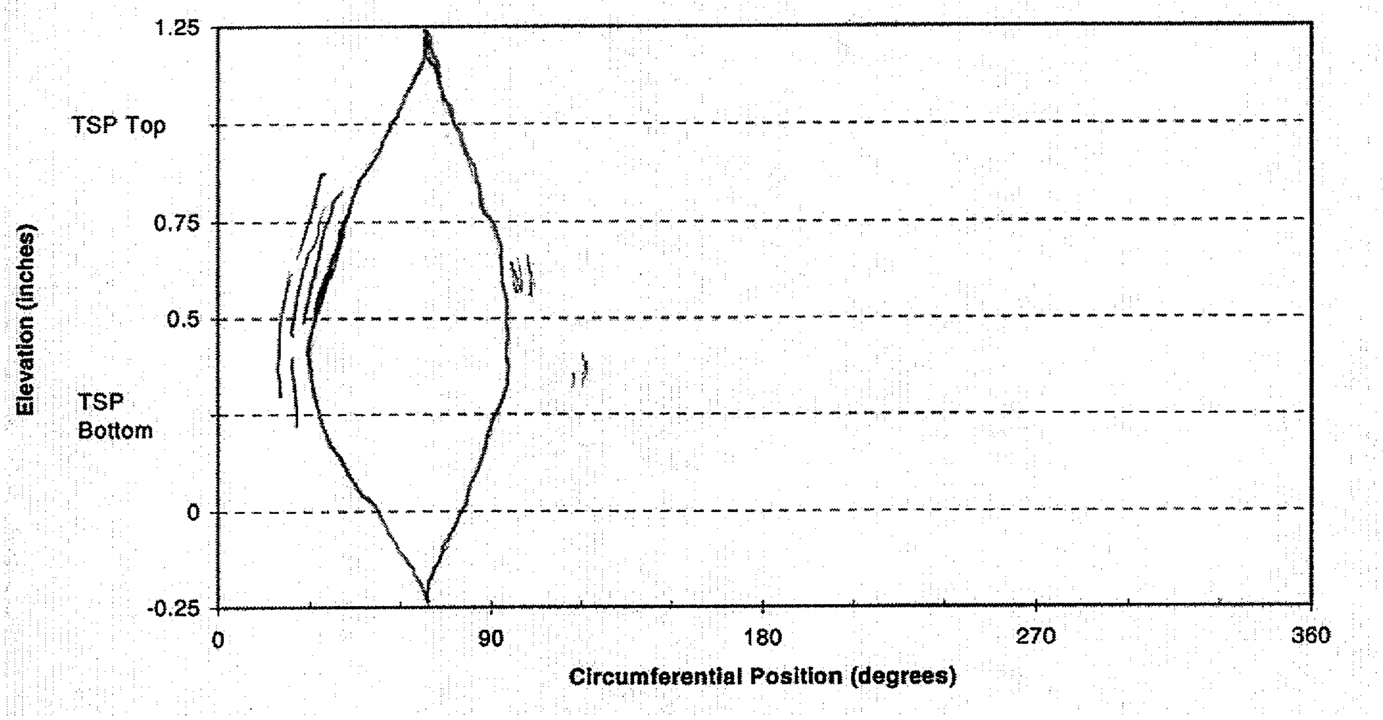
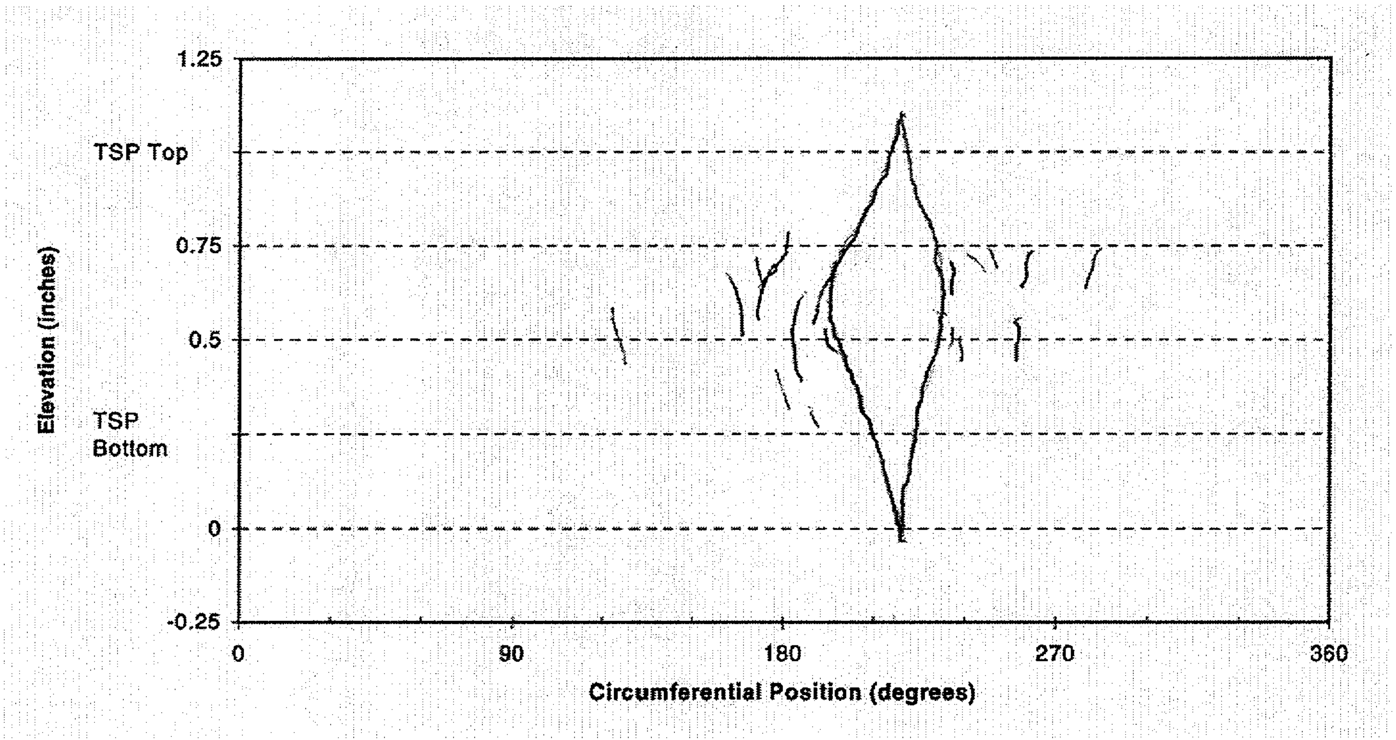


Figure 3-4
Sketch of Burst Opening – Tube R31C81 – TSP-H5 Location



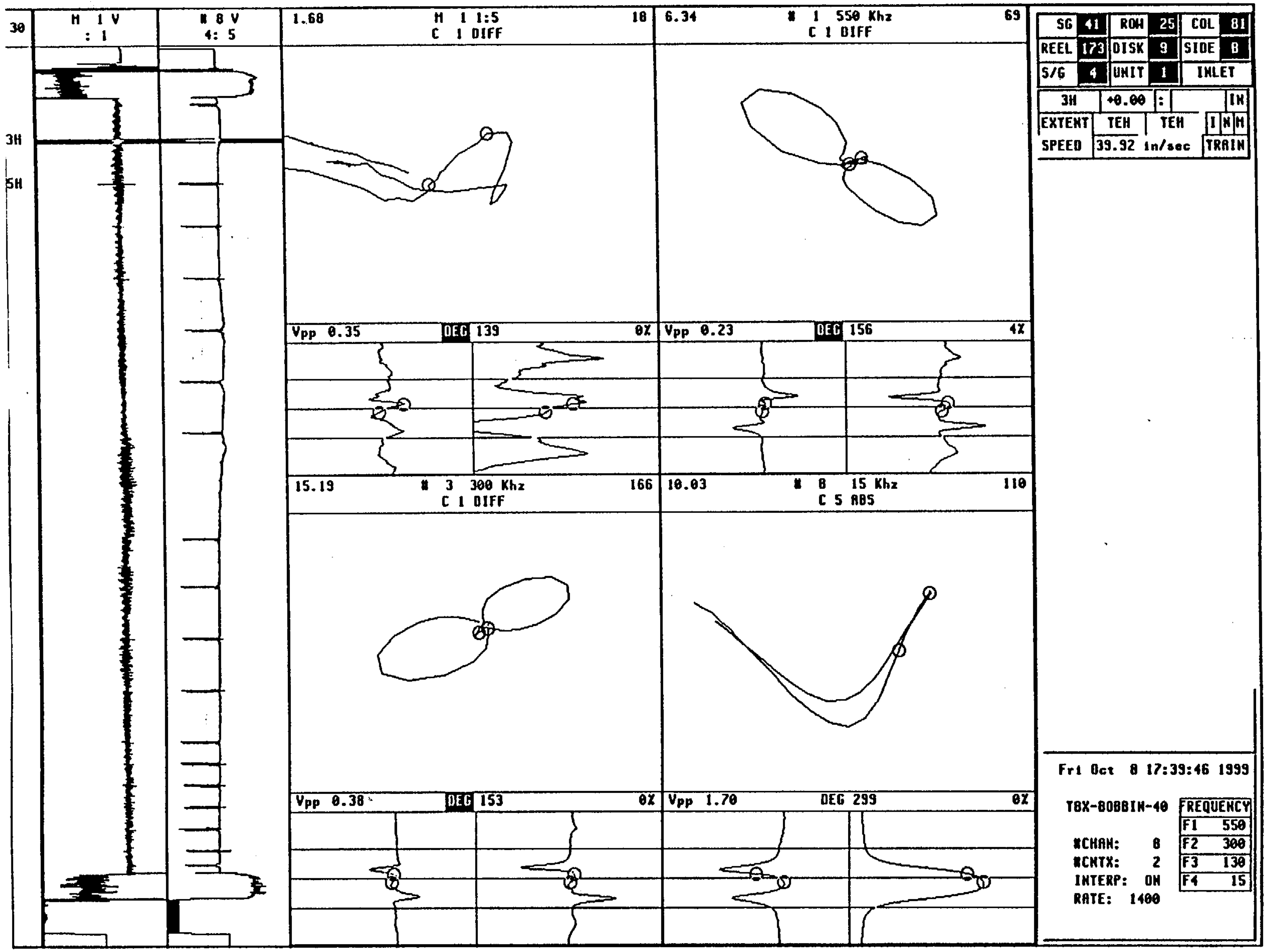


Figure 3-5
Comanche Peak Unit-1 R25C81 TSP 3H Bobbin Signal Reevaluation

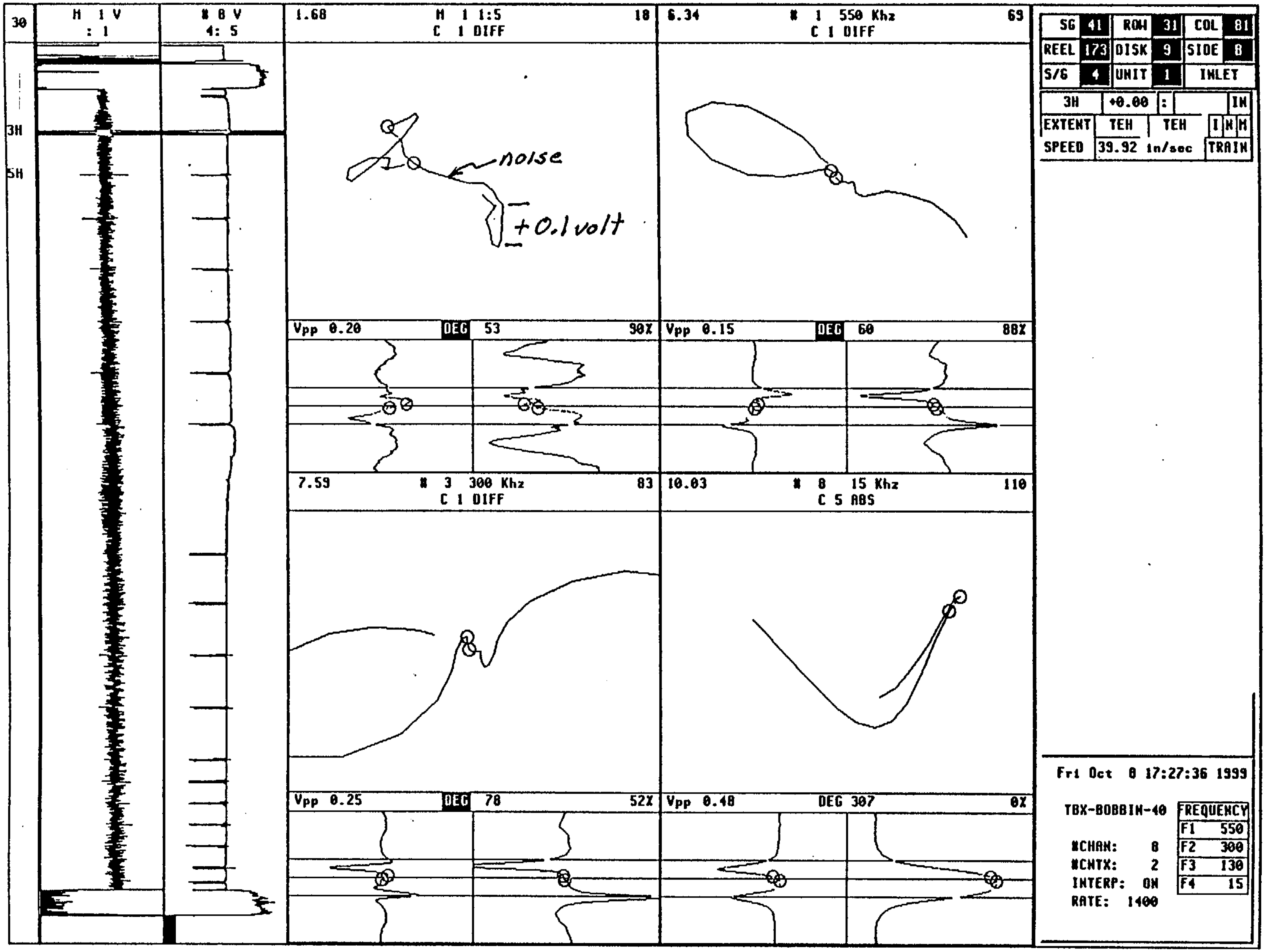


Figure 3-6
Comanche Peak Unit-1 R31C81 TSP 3H Bobbin Signal Reevaluation

Figure 3-7

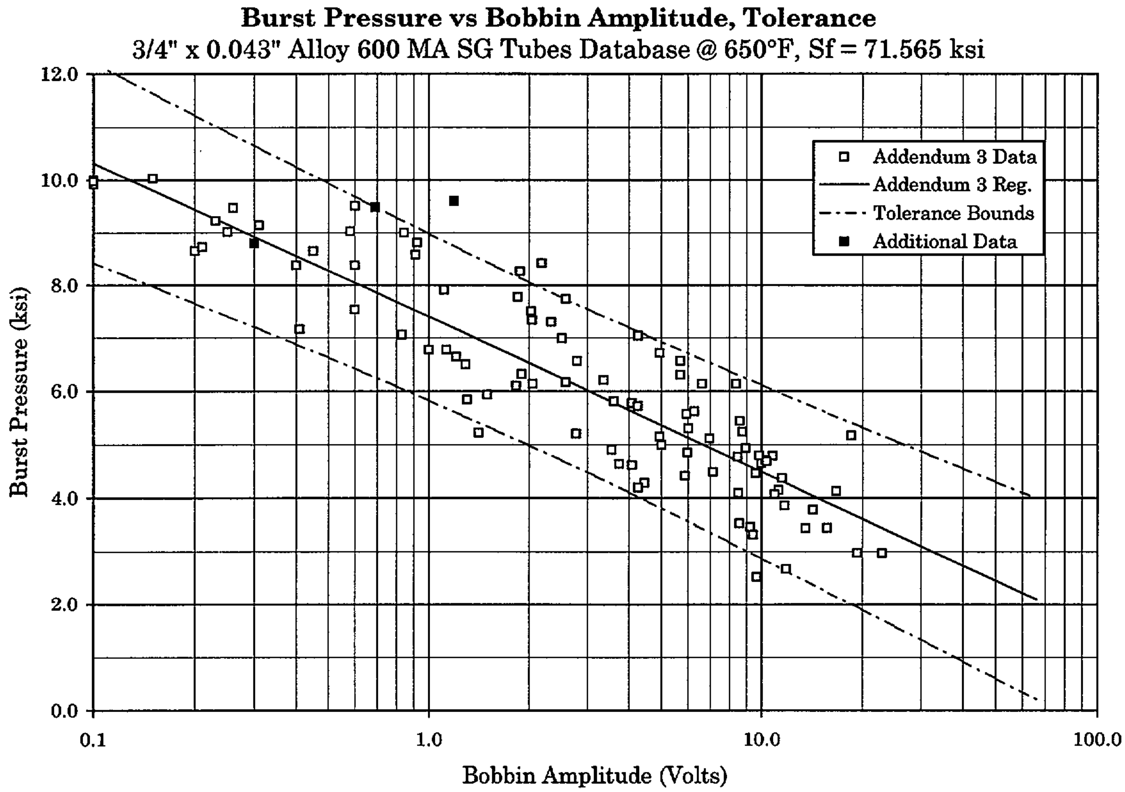


Figure 3-8

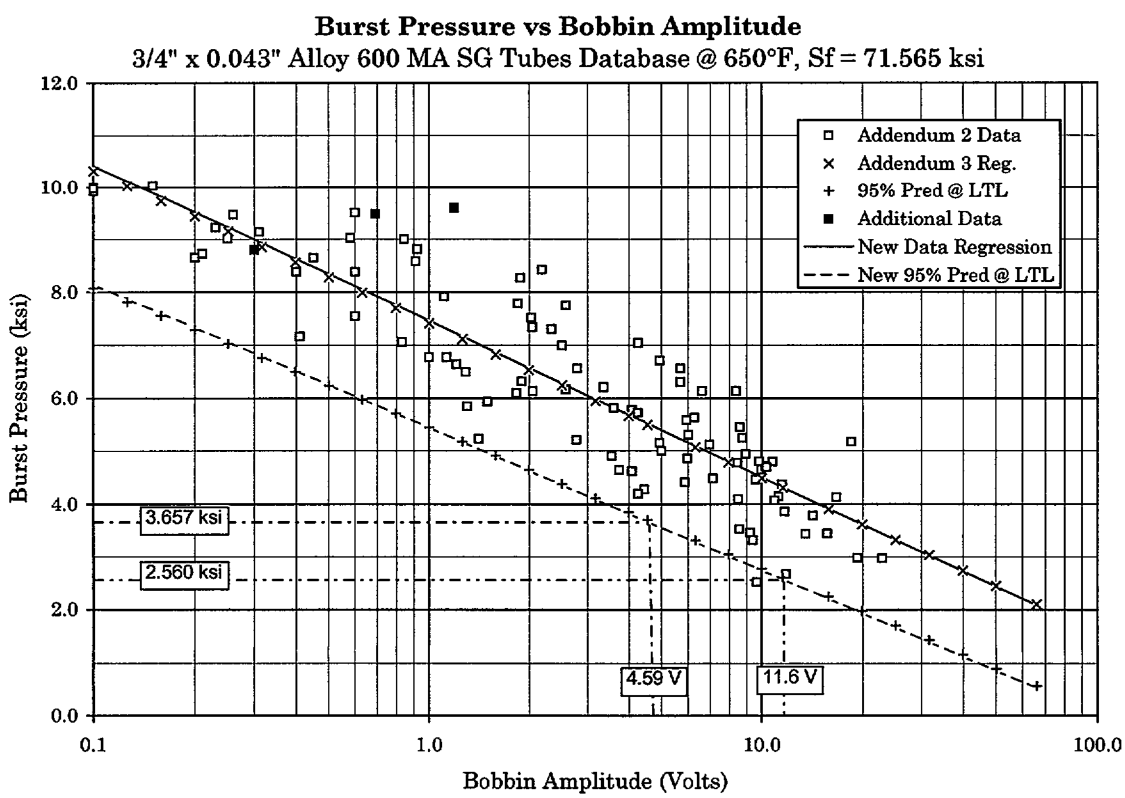
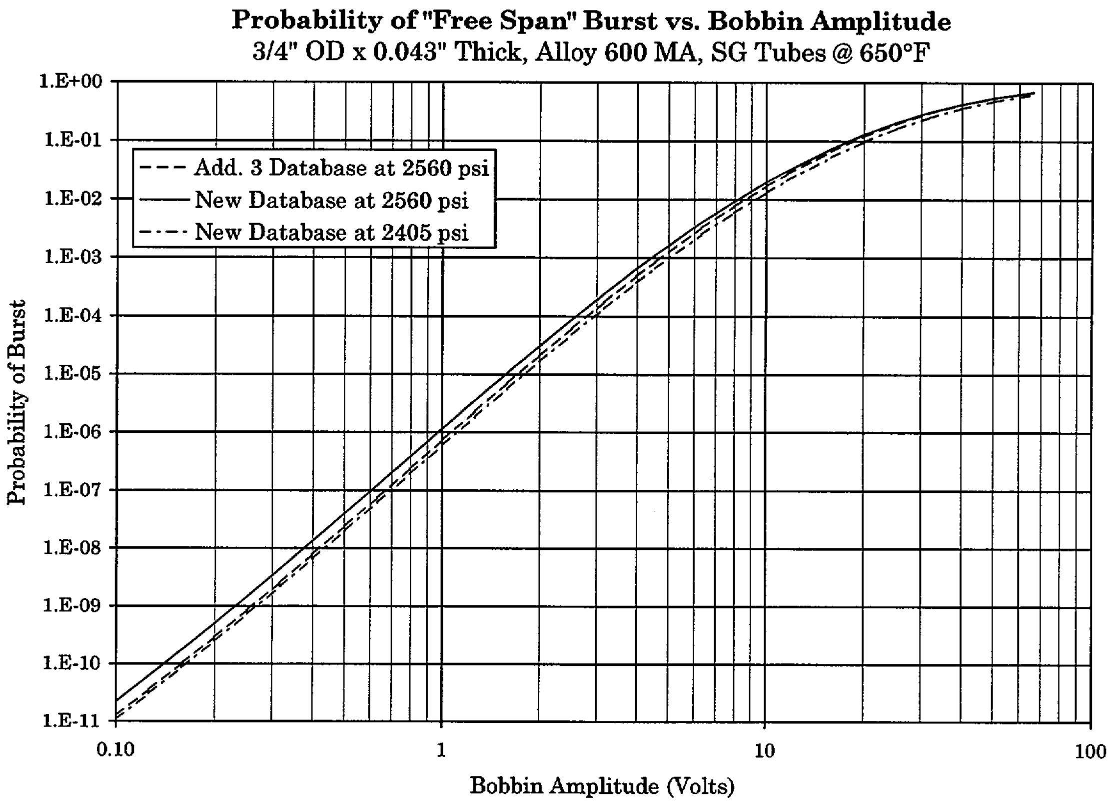


Figure 3-9



Probability of "Free Span" Burst vs. Bobbin Amplitude
3/4" OD x 0.043" Thick, Alloy 600 MA, SG Tubes @ 650°F
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
Probability of Burst
Add. 3 Database at 2560 psi
New Database at 2560 psi
New Database at 2405 psi
0.10
1
10
100
Bobbin Amplitude (Volts)

Figure 3-10

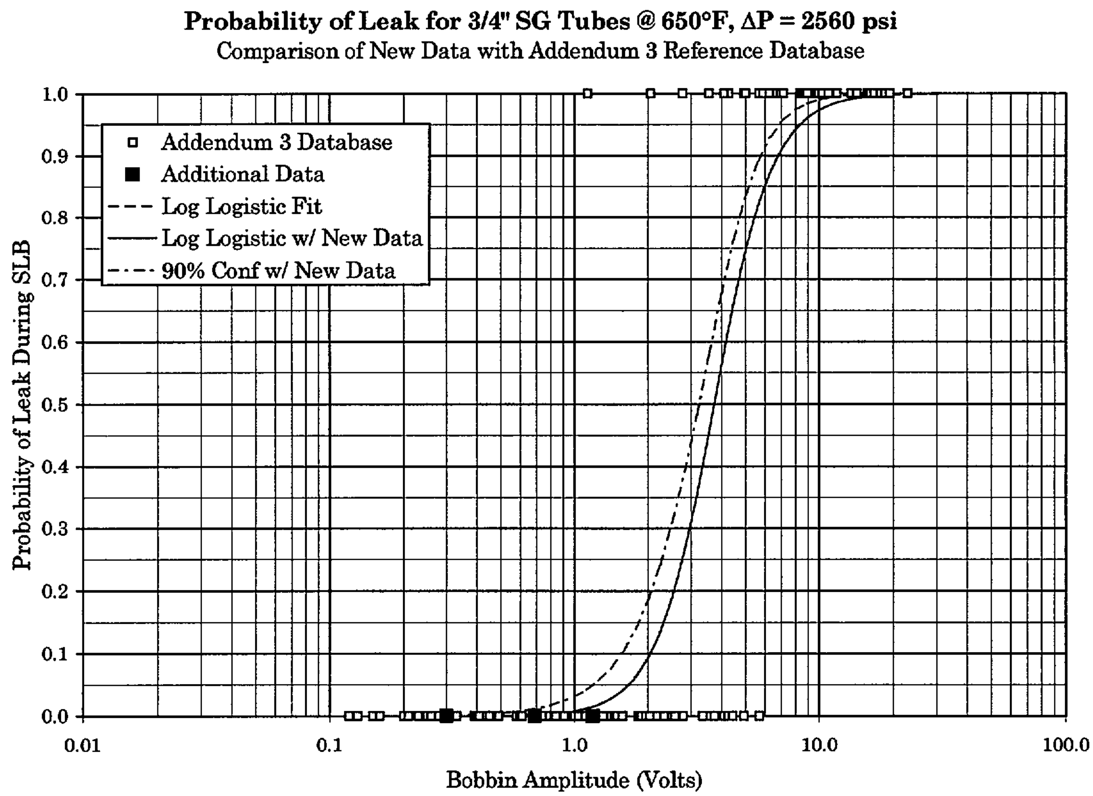
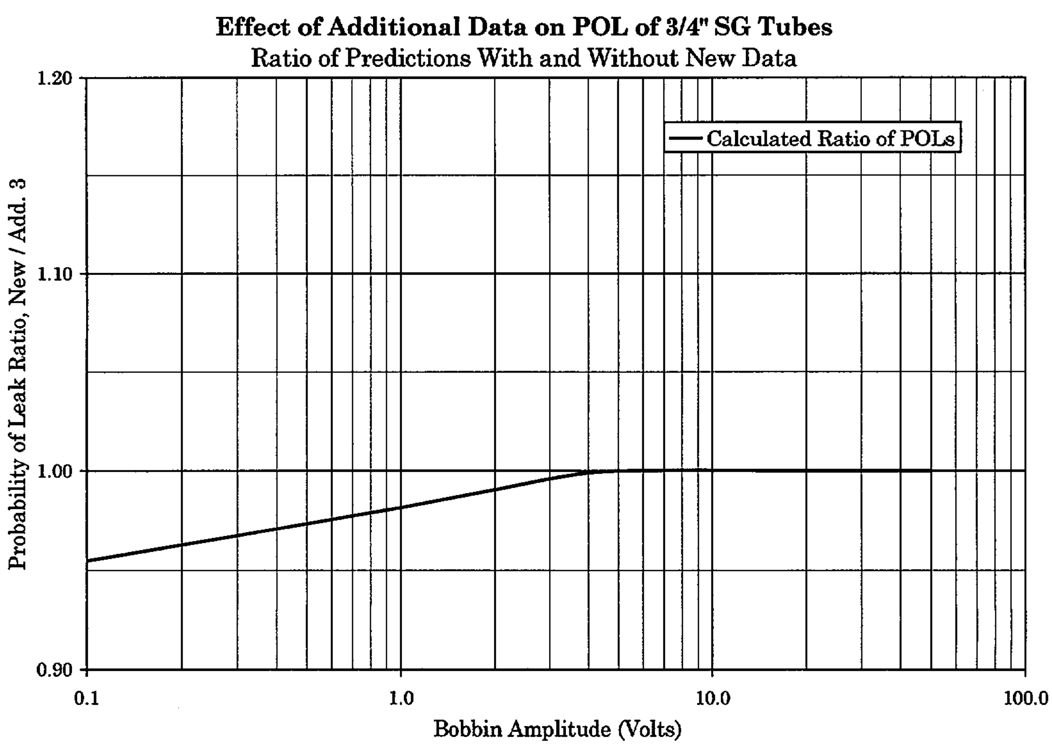


Figure 3-11



4.0 EOC-7 Inspection Results and Voltage Growth Rates

4.1 EOC-7 Inspection Results

According to the guidance provided by the NRC Generic Letter 95-05, the EOC-7 inspection of the Comanche Peak Unit-1 SGs consisted of a complete, 100% eddy current (EC) bobbin probe full length examination of the tube bundles in all four SGs. A 0.610 inch diameter probe was used for hot and cold leg TSPs where a voltage-based repair criterion was applied. RPC examination was performed for all indications with amplitude above 1 volt. Only one indication in the combined population from all 4 SGs exceeded 1 volt. It was confirmed as a flaw, and the tube containing it was pulled for detailed laboratory examination. All ODSCC indications detected at TSPs were on the hot leg side and no indication was detected on the cold leg side.

No ID, circumferential indications at the TSP intersections or indications extending outside the TSP were found in this inspection. Only one mixed residual signal at TSP intersection that could potentially mask a 1.0 volt bobbin indication (residual signal voltage 1.5 volts or greater) was detected in this inspection (in SG-3); it was inspected with a RPC probe and no degradation was detected. No signal interference was found from copper deposits. All dents over 5 volts identified in the last (EOC-6) inspection were also RPC inspected in present inspection, and no degradation was detected.

A summary of EC indications for all four SGs is shown on Table 4-1, which tabulates the number of field bobbin indications, the number of those indications that were RPC inspected, the number of RPC confirmed indications, and the number of indications removed from service due to tube repairs. The indications that remain active for Cycle 8 operation is the difference between the observed and the ones removed from service. Only one indication needed repairs per the GL 95-05 requirements. Two more indications, both under 1 volt, were also removed from service as they were present in tubes pulled for laboratory examination per GL 95-05 requirements. Figure 4-1 shows the actual bobbin voltage distribution determined from the EOC-7 EC inspection. Since only a total 3 ODSCC indications were removed from service because of tube repairs for all causes, the distribution in Figure 4-1 also approximates the distribution for indications returned to service for Cycle 8.

A review of Table 4-1 indicates that SG-4 had the highest number of indications returned to service for Cycle 8 operation (62 indications, none above 1.0 volt). Therefore, SG-4 is likely to be the limiting SG at EOC-8 from the standpoint of SLB leak rate and tube burst probability.

The distribution of EOC-7 indications as a function of support plate location is summarized in Table 4-2 and plotted in Figure 4-2. The data show a strong predisposition of ODSCC to occur in the first few hot leg TSPs (99 out of 104 indications occurred at the hot leg intersections in the two TSPs above the flow distribution baffle plate), although the mechanism extended to higher TSPs. No ODSCC indications were found on the cold leg side. In summary, the distribution of indication population at TSPs in Comanche Peak Unit-1 show the predominant temperature dependence of ODSCC, similar to that observed at other plants.

The TSP ODSCC mechanism at Comanche Peak Unit-1 is still benign. As a comparison, a plant with Model E2 steam generators reported 2262 indications, with 17 indications over 3 volts, and another plant with Model D4 steam generators reported 5719 indications, with 7 indications over 3 volts, after 7 cycles of operation. The application of chemical cleaning at

Comanche Peak Unit-1 1RF05 outage appears to have had a significant beneficial impact upon ODSCC initiation and growth rates.

4.2 Voltage Growth Rates

Voltage growth rates during Cycle 7 were developed from EOC-7 (September 1999) inspection data and a reevaluation of the EOC-6 (April 1998) inspection EC signals for the same indications. Table 4-3 shows the cumulative probability distribution (CPDF) for growth rate in each Comanche Peak Unit-1 steam generator during Cycle 7 on an EFPY basis, and they are also plotted in Figure 4-3. The curve labeled 'cumulative' in Figure 4-3 represents composite growth data from all four SGs. No growth rate evaluation was performed for prior cycles because a voltage-based criterion was not used prior to the current cycle.

Average growth rates for each SG during Cycle 7 are summarized in Table 4-4. It is evident that the magnitude of average voltage growth in all SGs is relatively small (about 0.1 volt or less). In terms of growth as a percent of the BOC voltage, the data for SG-3 stands out (21.1%); but this value is based on data from only 9 indications and, thus, does not indicate a trend.

The NRC guidelines in Generic Letter 95-05 stipulate that the growth rate distribution(s) used in the SLB leak rate and tube probability analyses to support voltage-based repair criteria must contain at least 200 data points that are established using bobbin voltages measured in two consecutive inspections. Since the composite growth data in Table 4-3 is based on only 104 indications, the Cycle 7 growth data do not meet the above NRC requirement. In the absence of an acceptable plant-specific growth database, the Generic Letter 95-05 requires the use of a bounding growth rate distribution established based on data available from similarly designed and operated plants. Therefore, a bounding growth distribution was developed using available growth data for plants with ¾ inch diameter tubes and applied to the Comanche Peak Unit-1 EOC-8 projections.

Prior to Comanche Peak Unit-1, voltage-based repair criteria for ODSCC indications have been applied to five units with ¾ inch diameter tubes. Growth data from these 5 units were used to develop a bounding growth distribution for ¾" tube plants. Only the growth data for operating periods during which a 1-volt repair criterion was in effect were included. The growth data from different plants were expressed as growth rates per EFPY to account for different plant operating periods. The largest growth rates for each of these 5 units in a cycle when a 1-volt repair criterion was in effect, expressed as a cumulative probability distribution, are shown in Table 4-5; they are also plotted in Figure 4-4. The plant codes used in Table 4-5 and Figure 4-4 are same as those in the EPRI database documented in Reference 9-4. All of the bobbin voltage data used in the growth data considered have been evaluated using the inspection guidelines employed since 1992 to support voltage-based repair criteria. It is evident that the largest growth rates for the individual units vary significantly.

Using the growth distributions for the 5 units, a bounding growth distribution for plants with 3/4 inch diameter tubes was obtained so as to envelope all five growth rate distributions considered; it is shown in Table 4-5 as well as plotted in Figure 4-4. This bounding distribution follows the growth rates observed during the first half of Cycle 5 for Plant AA, but it also includes the highest growth value in the 5 distributions, which occurred in Plant-AB. The bounding growth distribution thus obtained is also compared with the CPDF distribution for the Comanche Peak Unit-1 last cycle growth data in Table 4-5 and Figure 4-4, and it is clearly evident that the Comanche Peak Unit-1 growth rates are significantly smaller than the bounding values. The CPDF values defining the bounding distribution are utilized to predict the EOC-8 voltage distributions used in the SLB leak rate and tube burst analyses.

4.3 NDE Uncertainties

The NDE uncertainties applied for the Cycle 7 voltage distributions in the Monte Carlo analyses for leak rate and burst probabilities are consistent with the requirements of the NRC Generic Letter 95-05 (Reference 9-1). They are presented in Table 4-6 as well as graphically illustrated in Figure 4-5. 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 for SLB leak rates and tube burst probabilities based on the EOC-7 actual voltage distributions as well as for the EOC-8 projections.

4.4 Probability of Prior Cycle Detection (POPCD)

Since the ODSCC indication population in Comanche Peak Unit-1 is relatively small, adequate data does not exist to establish a POPCD distribution. If a significantly larger number of indications are detected in future inspections, then a POPCD evaluation may be performed.

4.5 Probe Wear Criteria

An alternate probe wear criteria approved by the NRC (Reference 9-5) was applied during the EOC-7 inspection. When a probe does not pass the 15% wear limit, this alternate criteria requires that only tubes with indications above 75% of the repair limit since the last successful probe wear check be reinspected. As the repair limit is 1 volt, all tubes containing indications for which worn probe voltage was above 0.75 volt require reinspection. Only 11 indications detected had a field bobbin voltage over 0.75 volts and none of those indications were inspected with a worn probe. Therefore, no reinspection was required.

The alternate probe wear criteria used in the EOC-7 inspection is consistent with the NRC guidance provided in Reference 9-5.

Table 4-1
Comanche Peak Unit 1 September 99 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 7

Voltage Bin	Steam Generator 1						Steam Generator 2					
	In-Service During Cycle 7				RTS for Cycle 8		In-Service During Cycle 7				RTS for Cycle 8	
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.2	2	0	0	0	2	2	1	0	0	0	1	1
0.3	1	0	0	0	1	1	3	0	0	0	3	3
0.4	5	0	0	0	5	5	3	0	0	0	3	3
0.5	1	0	0	0	1	1	5	0	0	0	5	5
0.6	1	0	0	0	1	1	2	0	0	0	2	2
0.7	1	0	0	0	1	1	4	0	0	0	4	4
0.8	0	0	0	0	0	0	0	0	0	0	0	0
0.9	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0	1	1
1.2	0	0	0	0	0	0	0	0	0	0	0	0
Total	11	0	0	0	11	11	19	0	0	0	19	19
>1v	0	0	0	0	0	0	0	0	0	0	0	0

Voltage Bin	Steam Generator 3						Steam Generator 4					
	In-Service During Cycle 7				RTS for Cycle 8		In-Service During Cycle 7				RTS for Cycle 8	
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.2	1	0	0	0	1	1	1	0	0	0	1	1
0.3	1	0	0	0	1	1	14	0	0	0	14	14
0.4	2	0	0	0	2	2	7	0	0	0	7	7
0.5	2	0	0	0	2	2	5	0	0	0	5	5
0.6	1	0	0	0	1	1	14	0	0	0	14	14
0.7	1	0	0	0	1	1	13	2	0	2	11	11
0.8	1	0	0	0	1	1	4	0	0	0	4	4
0.9	0	0	0	0	0	0	3	0	0	0	3	3
1	0	0	0	0	0	0	3	0	0	0	3	3
1.2	0	0	0	0	0	0	1	1	1	1	0	0
Total	9	0	0	0	9	9	65	3	1	3	62	62
>1v	0	0	0	0	0	0	1	1	1	1	0	0

Table 4-2
Comanche Peak Unit 1 September 1999
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 7

Tube Support Plate	Steam Generator 1					Steam Generator 2				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
H3	7	0.59	0.32	0.04	-0.03	13	0.92	0.54	0.13	-0.01
H5	4	0.62	0.42	0.07	0.01	5	0.38	0.32	0.02	0.00
H7	0	-	-	-	-	0	-	-	-	-
H10	0	-	-	-	-	1	0.44	0.44	0.15	0.15
Total	11					19				

Tube Support Plate	Steam Generator 3					Steam Generator 4				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
H3	9	0.75	0.44	0.38	0.10	43	0.97	0.54	0.22	-0.01
H5	0	-	-	-	-	18	1.20	0.53	0.13	0.01
H7	0	-	-	-	-	4	0.62	0.38	0.03	0.01
H10	0	-	-	-	-	0	-	-	-	-
Total	9					65				

Table 4-3
Comanche Peak Unit 1 September 99
Signal Growth Statistics For Cycle 7 on an EFPY Basis

Delta Volts	Steam Generator 1		Steam Generator 2		Steam Generator 3		Steam Generator 4		Cumulative	
	No. of Inds	CPDF	No. of Inds	CPDF	No. of Inds	CPDF	No. of Inds	CPDF	No. of Inds	CPDF
-0.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
-0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
-0.1	0	0.0	0	0.0	0	0.0	1	0.015	1	0.01
0	7	0.636	10	0.526	1	0.111	38	0.6	56	0.548
0.1	4	1.0	8	0.947	7	0.889	22	0.938	41	0.942
0.2	0		1	1.0	0	0.889	4	1.0	5	0.99
0.3	0		0		1	1.0	0		1	1.0
0.8	0		0		0		0		0	
Total	11		19		9		65		104	

Table 4-4
Comanche Peak Unit 1 - September 1999 Outage
Average Voltage Growth During Cycle 7

Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Percent Growth	
			Entire Cycle	Per EFPY #	Entire Cycle	Per EFPY #
	Composite of All Steam Generator Data					
Entire Voltage Range	104	0.49	0.003	0.002	0.6%	0.4%
V BOC < .75 Volts	90	0.43	0.012	0.009	2.8%	2.0%
> .75 Volts	14	0.89	-0.056	-0.040	-6.4%	-4.6%
	Steam Generator 1					
Entire Voltage Range	11	0.38	-0.019	-0.014	-5.1%	-3.6%
V BOC < .75 Volts	11	0.38	-0.019	-0.014	-5.1%	-3.6%
> .75 Volts	0	0.00	0.000	0.000	-	-
	Steam Generator 2					
Entire Voltage Range	19	0.48	-0.002	-0.001	-0.3%	-0.2%
V BOC < .75 Volts	16	0.41	0.018	0.013	4.3%	3.1%
> .75 Volts	3	0.84	-0.103	-0.074	-12.3%	-8.8%
	Steam Generator 3					
Entire Voltage Range	9	0.34	0.101	0.072	29.5%	21.1%
V BOC < .75 Volts	9	0.34	0.101	0.072	29.5%	21.1%
> .75 Volts	0	0.00	0.000	0.000	-	-
	Steam Generator 4					
Entire Voltage Range	65	0.53	-0.006	-0.004	-1.1%	-0.8%
V BOC < .75 Volts	54	0.46	0.002	0.001	0.4%	0.3%
>.75 Volts	11	0.90	-0.044	-0.031	-4.9%	-3.5%

Based on Cycle 7 duration of 510.4 EFPD (1.397 EFPY)

Table 4-5
Distribution of Highest Growth Rates in 3/4" Tube Plants
While a 1 volt Repair Criterion was in Effect

Delta Volts	Plant AA	Plant AB	Plant AC-1	Plant AC-2	Plant R	Bounding Distribution	Comanche Peak Unit-1, Cycle 7
	Cumulative Probability Distributions						
-0.5	0.0000	0.0003	0.0000	0.0000	0.0049	0.0000	
-0.4	0.0015	0.0010	0.0000	0.0009	0.0101	0.0000	
-0.3	0.0064	0.0052	0.0006	0.0010	0.0182	0.0000	
-0.2	0.0193	0.0237	0.0052	0.0018	0.0327	0.0000	0.0000
-0.1	0.0659	0.0598	0.0354	0.0133	0.0683	0.0000	0.0096
0.0	0.2109	0.1285	0.3041	0.1026	0.1778	0.1026	0.5481
0.1	0.3648	0.2927	0.7964	0.4439	0.4115	0.2927	0.9423
0.2	0.5100	0.4761	0.9343	0.7573	0.6436	0.4761	0.9904
0.3	0.6290	0.6332	0.9774	0.8687	0.7978	0.6290	1.0000
0.4	0.7225	0.7551	0.9897	0.9218	0.8842	0.7225	
0.5	0.7902	0.8449	0.9929	0.9456	0.9341	0.7902	
0.6	0.8401	0.9021	0.9955	0.9580	0.9611	0.8401	
0.7	0.8836	0.9398	0.9968	0.9668	0.9746	0.8836	
0.8	0.9099	0.9616	0.9968	0.9695	0.9842	0.9099	
0.9	0.9264	0.9763	0.9974	0.9735	0.9909	0.9264	
1.0	0.9408	0.9828	0.9987	0.9770	0.9933	0.9408	
1.1	0.9534	0.9850	0.9987	0.9792	0.9953	0.9534	
1.2	0.9616	0.9883	0.9987	0.9801	0.9971	0.9616	
1.3	0.9694	0.9896	0.9987	0.9819	0.9977	0.9694	
1.4	0.9758	0.9919	0.9987	0.9832	0.9979	0.9758	
1.5	0.9802	0.9935	0.9987	0.9863	0.9982	0.9802	
1.6	0.9817	0.9948	0.9987	0.9881	0.9984	0.9817	
1.7	0.9848	0.9954	0.9987	0.9889	0.9990	0.9848	
1.8	0.9858	0.9964	0.9987	0.9898	0.9990	0.9858	
1.9	0.9884	0.9964	0.9987	0.9907	0.9990	0.9884	
2.0	0.9889	0.9967	0.9987	0.9907	0.9990	0.9889	
2.1	0.9902	0.9967	0.9994	0.9916	0.9995	0.9902	
2.2	0.9915	0.9967	1.0	0.9929	0.9995	0.9915	
2.3	0.9925	0.9974		0.9934	0.9995	0.9925	
2.4	0.9938	0.9980		0.9934	0.9995	0.9934	
2.5	0.9949	0.9980		0.9938	0.9995	0.9934	
2.6	0.9954	0.9980		0.9938	0.9997	0.9938	
2.7	0.9961	0.9980		0.9943	0.9997	0.9938	
2.8	0.9967	0.9980		0.9956	0.9997	0.9956	
2.9	0.9977	0.9984		0.9969	0.9997	0.9969	
3.0	0.9977	0.9987		0.9978	0.9997	0.9977	
3.1	0.9982	0.9987		0.9978	0.9997	0.9978	
3.2	0.9987	0.9987		0.9978	0.9997	0.9978	
3.3	0.9990	0.9987		0.9978	0.9997	0.9978	
3.4	0.9992	0.9987		0.9987	0.9997	0.9978	
3.8	0.9995	0.9987		0.9991	0.9997	0.9987	
4.0	0.9997	0.9987		0.9991	0.9997	0.9987	
4.1	0.9997	0.9987		1.0	0.9997	0.9987	
4.3	0.9997	0.9990			0.9997	0.9987	
4.7	0.9997	0.9993			1.0	0.9987	
5.3	0.9997	0.9997				0.9997	
5.7	1.0	0.9996748				0.9997	
7.8		1.0				1.0	

Table 4-6
Probe Wear and Analyst Variability - Tabulated Values

Analyst Variability		Probe Wear Variability	
Std. Dev = 10.3%	Mean = 0.0%	Std. Dev = 7.0%	Mean = 0.0%
No Cutoff		Cutoff at +/- 15%	
Value	Cumul. Prob.	Value	Cumul. Prob.
-40.0%	0.00005	< -15.0%	0.00000
-38.0%	0.00011	-15.0%	0.01606
-36.0%	0.00024	-14.0%	0.02275
-34.0%	0.00048	-13.0%	0.03165
-32.0%	0.00095	-12.0%	0.04324
-30.0%	0.00179	-11.0%	0.05804
-28.0%	0.00328	-10.0%	0.07656
-26.0%	0.00580	-9.0%	0.09927
-24.0%	0.00990	-8.0%	0.12655
-22.0%	0.01634	-7.0%	0.15866
-20.0%	0.02608	-6.0%	0.19568
-18.0%	0.04027	-5.0%	0.23753
-16.0%	0.06016	-4.0%	0.28385
-14.0%	0.08704	-3.0%	0.33412
-12.0%	0.12200	-2.0%	0.38755
-10.0%	0.16581	-1.0%	0.44320
-8.0%	0.21867	0.0%	0.50000
-6.0%	0.28011	1.0%	0.55680
-4.0%	0.34888	2.0%	0.61245
-2.0%	0.42302	3.0%	0.66588
0.0%	0.50000	4.0%	0.71615
2.0%	0.57698	5.0%	0.76247
4.0%	0.65112	6.0%	0.80432
6.0%	0.71989	7.0%	0.84134
8.0%	0.78133	8.0%	0.87345
10.0%	0.83419	9.0%	0.90073
12.0%	0.87800	10.0%	0.92344
14.0%	0.91296	11.0%	0.94196
16.0%	0.93984	12.0%	0.95676
18.0%	0.95973	13.0%	0.96835
20.0%	0.97392	14.0%	0.97725
22.0%	0.98366	15.0%	0.98394
24.0%	0.99010	> 15.0%	1.00000
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		

Figure 4-1
Comanche Peak Unit 1 September 1999 Outage
Bobbin Voltage Distributions at EOC-7 for Tubes in Service During Cycle 7

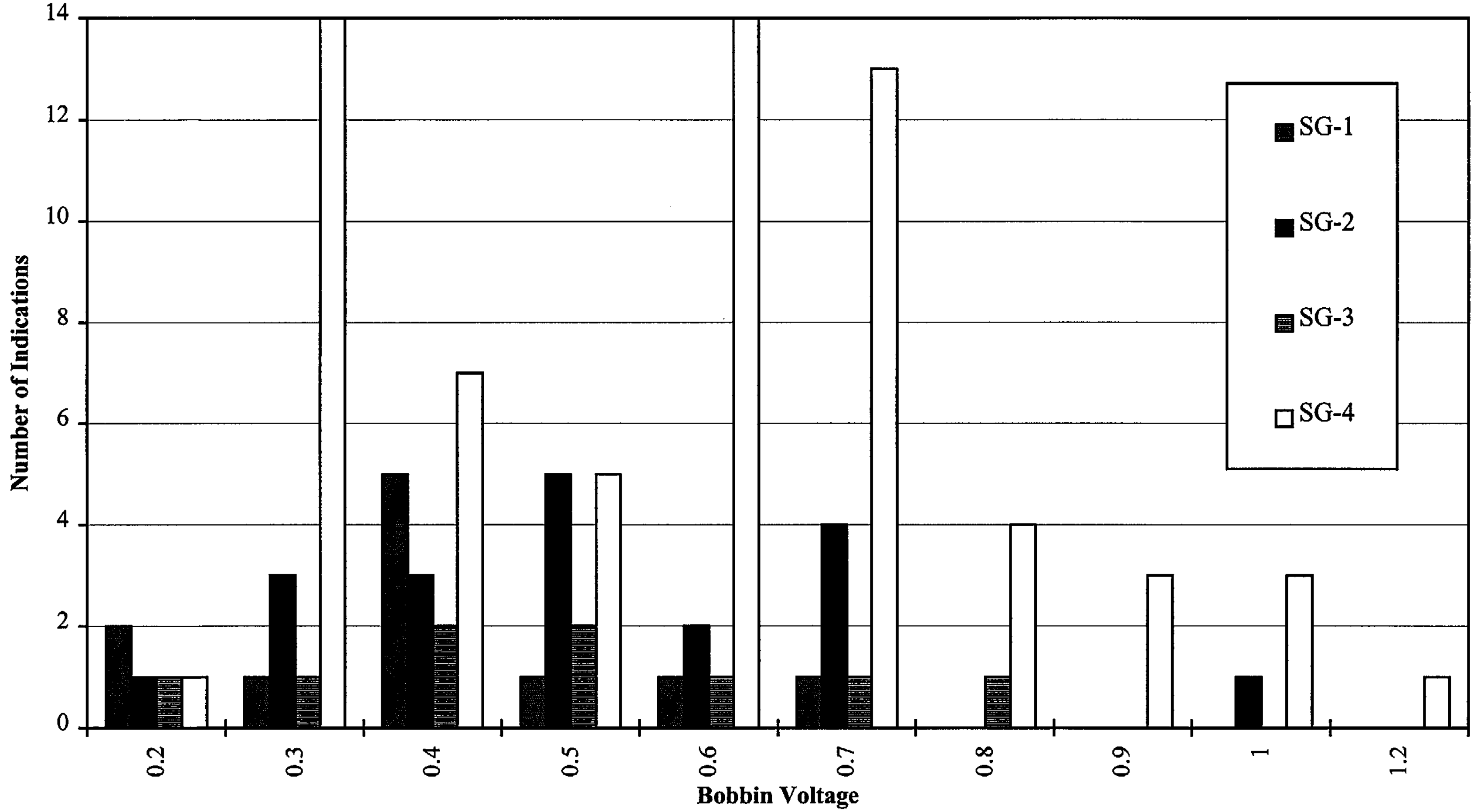


Figure 4-2
Comanche Peak Unit 1 - September 1999
ODSCC Axial Distributions for Tubes in Service During Cycle 7
[Note: According to TXU naming convention, H3 is the first hot leg TSP above the FDB]

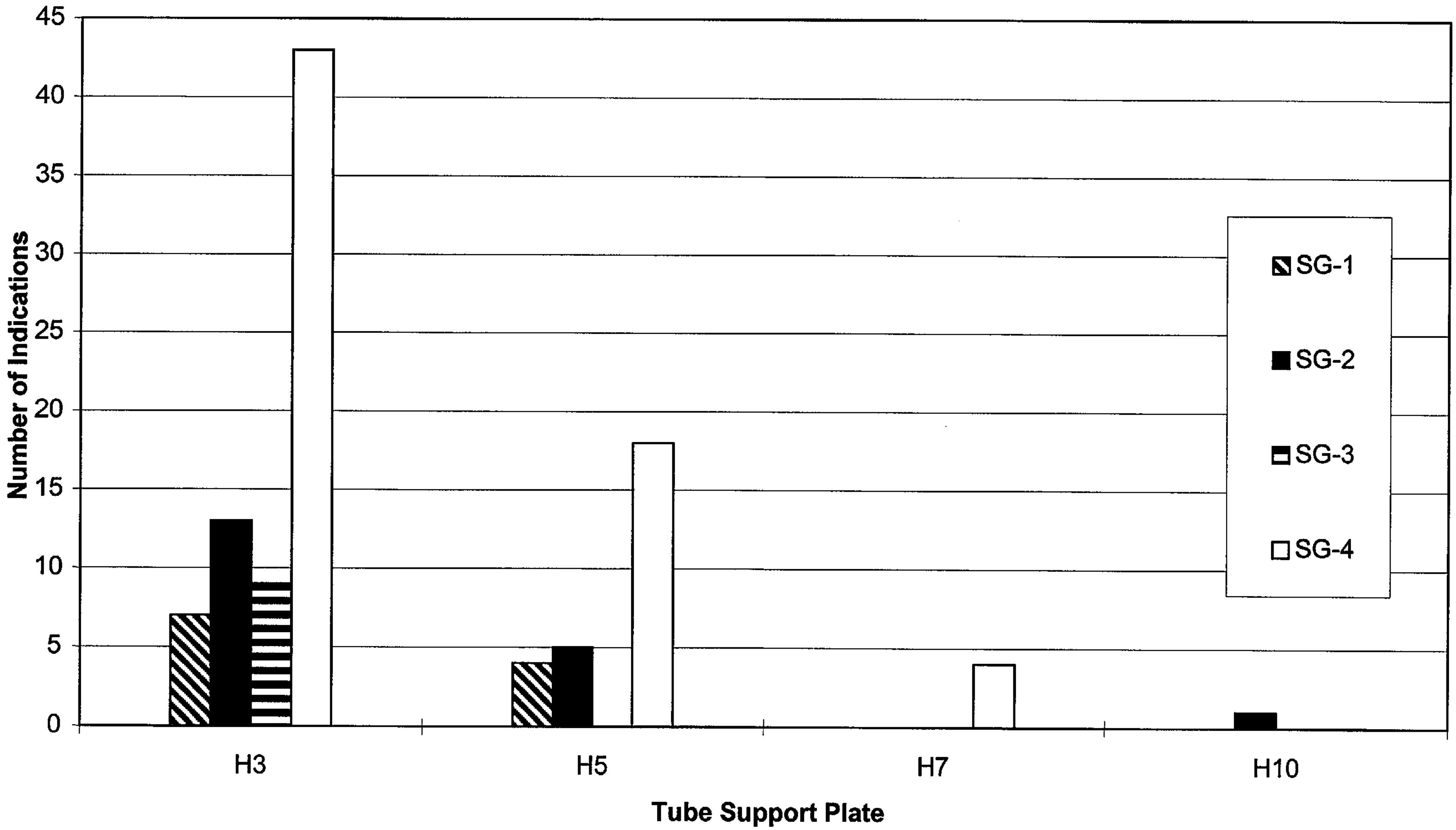


Figure 4-3
Comanche Peak Unit 1Cycle 7 (May 1998 to Sept. 1999)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

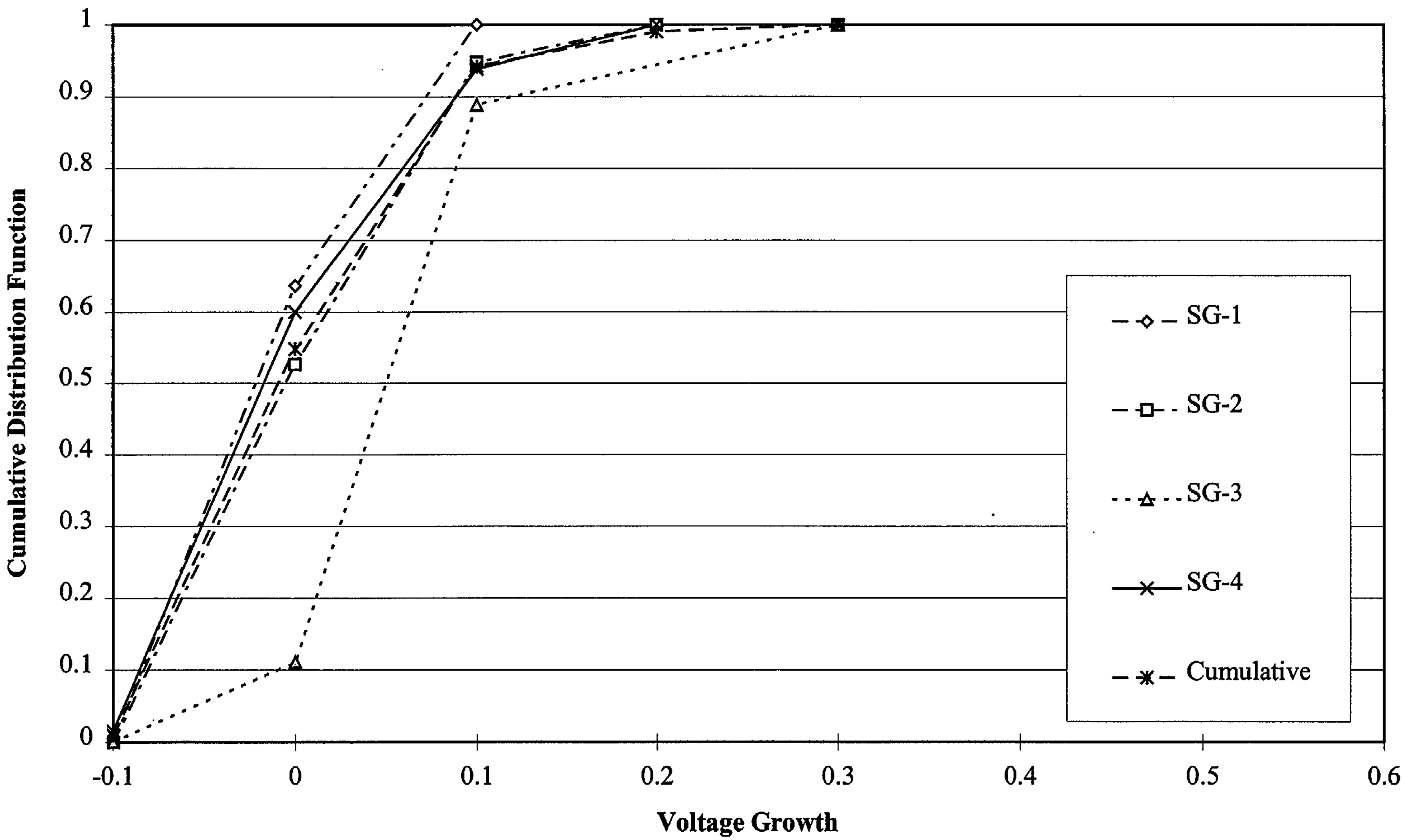


Figure 4-4
Distribution of Largest Growth Rates Observed in 3/4" Tube Plants
While a 1-volt Repair Criterion was Applied
Cumulative Probability Distributions for Voltage Growth on EFPY Basis

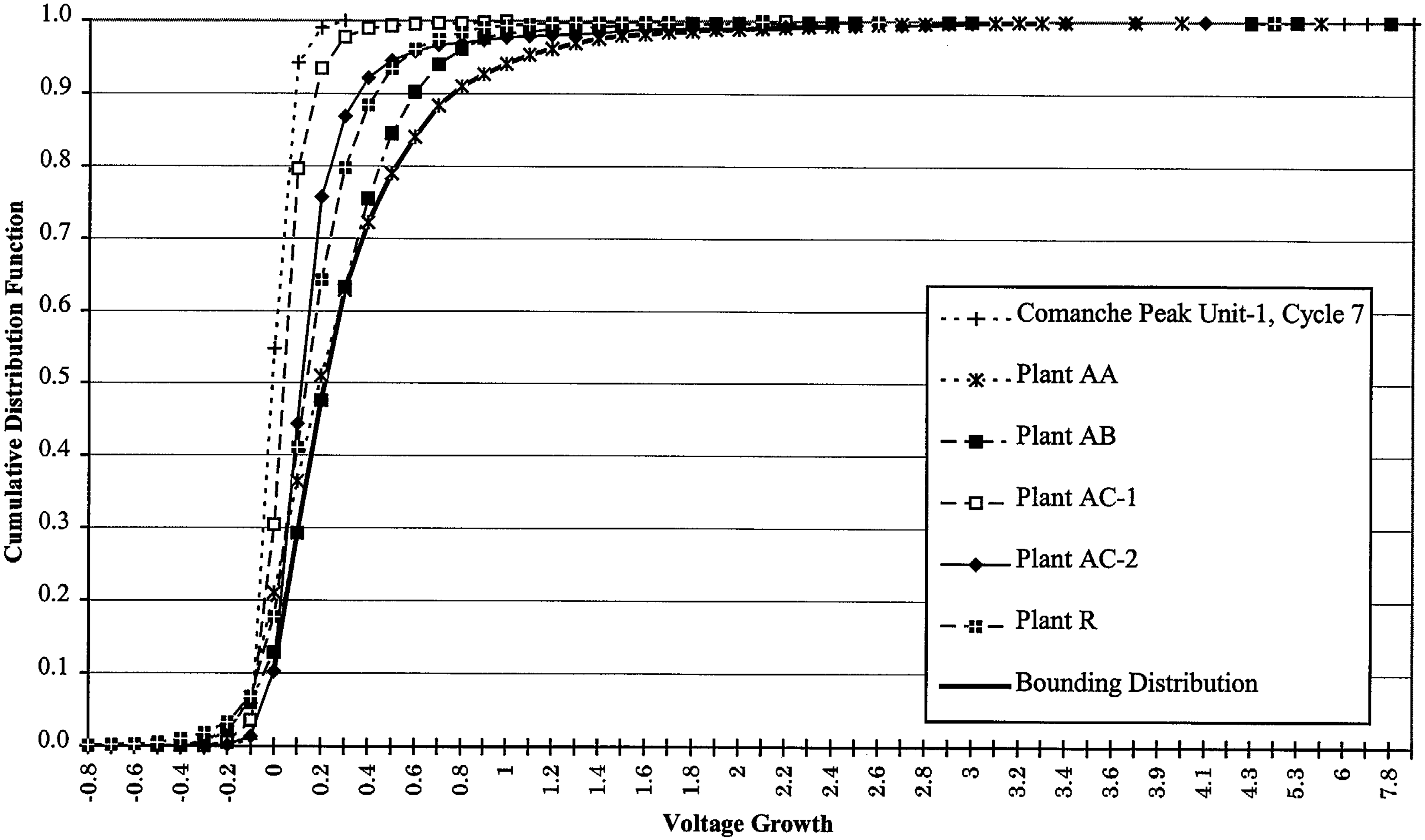
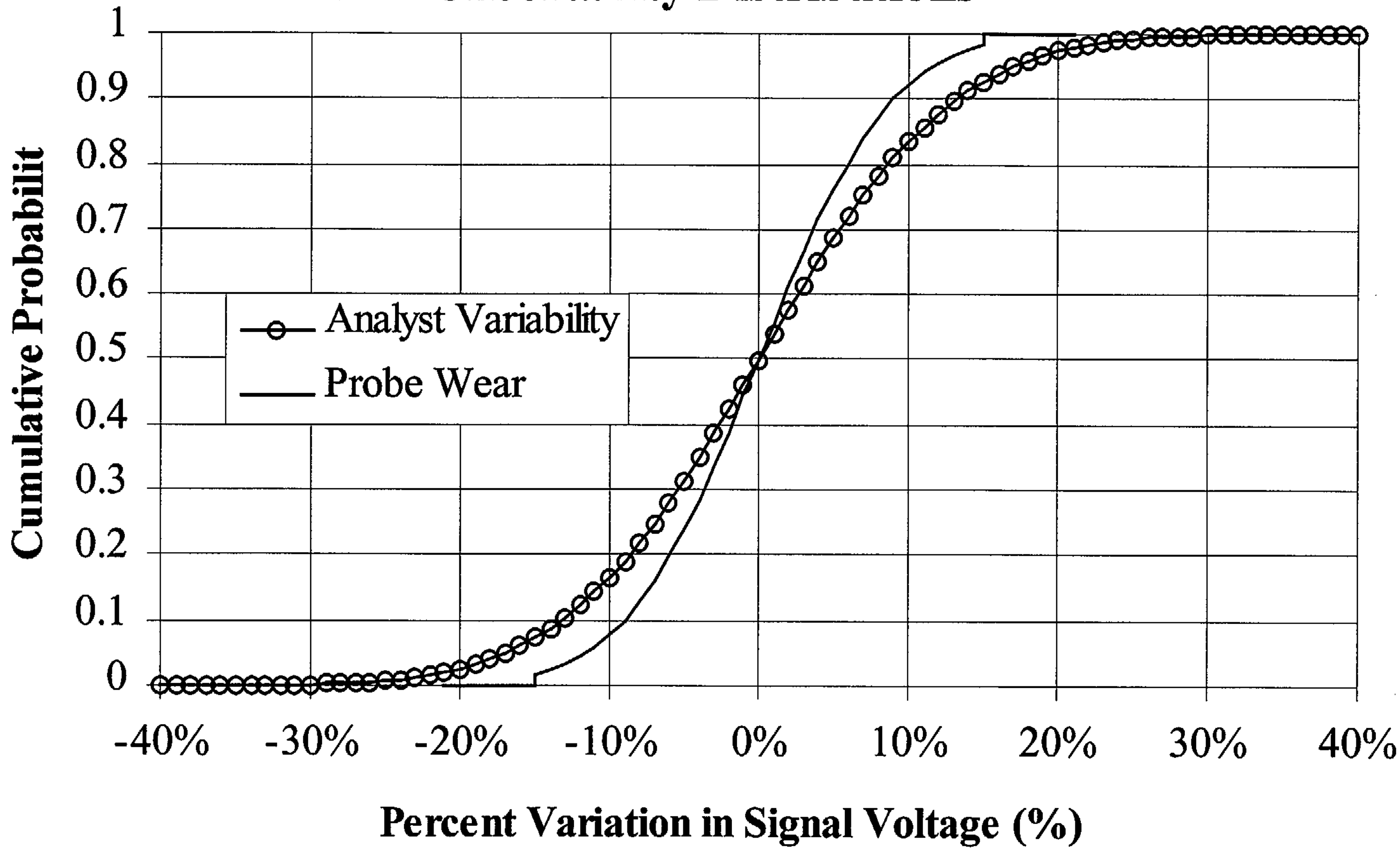


Figure 4-5
NDE Uncertainty Distributions



5.0 Database Applied for Leak and Burst Correlations

Leak and burst correlations based on the latest available database for ¾" tubes are applied in the analyses presented in this report, and these correlations are documented in Reference 9-6. This database does not include leak and burst data for tubes pulled recently from Comanche Peak Unit-1. An evaluation of the effects of adding the Comanche Peak Unit-1 data to the reference database in Reference 9-6 (described earlier in Section 3.3) indicates that the burst pressure, leak rate and the probability of leak correlations to the common logarithm of the bobbin amplitude are not be significantly changed. Therefore, SLB leak rates and burst probability analyses were carried out using the reference database presented in Reference 9-6. As a sensitivity study, EOC-8 projection for the limiting SG (SG-4) was also performed using the leak and burst correlation based on an updated base that included the Comanche Peak Unit-1 data, and those results are also presented in Section 8.

The reference database presented in Reference 9-6 meets the NRC requirement that the p value obtained from the regression analysis of leak rate be less than or equal to 5%. Therefore, a SLB leak rate versus voltage correlation is applied for the leak rate analyses. The following are the correlations for burst pressure, probability of leakage and leak rate used in this report (Reference 9-6).

$$\text{Burst Pressure } (ksi) = 7.40278 - 2.91382 \times \log(volts)$$

$$\text{Probability of Leak} = \frac{1}{1 + e^{\left(4.8082 - 8.4215 \times \log(volts)\right)}}$$

$$\text{Leak Rate } (l/hr) = 10^{\left(-1.63838 + 2.94093 \times \log(volts)\right)}$$

The upper voltage repair limit applied at the EOC-7 inspection, documented in Reference 9-7, was developed using the database presented in Reference 9-4. Since a more recent database is available now, the upper voltage repair limit data is revised below. The structural limit (V_{sl}) for the TSP indications established using 1.43 times the SLB ΔP of 2560 psid is 4.70 volts, and V_{sl} for the FDB intersections using 3 times normal operation ΔP value (3810 psid) is 4.20 volts. Using the minimum growth rate specified in the Generic Letter 95-05 (30%/EFPY)and a expected duration of 1.36 EFPY (496 EFPD) for Cycle 8, the growth allowance becomes 41%. The allowance for NDE uncertainty is 20% per Generic Letter 95-05. The upper voltage repair limits then become 2.92 volts for TSP indications and 2.61 volts for FDB indications. The bobbin voltage for the largest ODSCC indication found during the EOC-7 inspection (1.2 volts) is substantially below the revised upper repair limits.

6.0 SLB Analysis Methods

Monte Carlo analyses are used to calculate the SLB leak rates and tube burst probabilities for both actual EOC-7 and projected EOC-8 voltage distributions. The Monte Carlo analyses account for parameter uncertainty. The analysis methodology is described in the Westinghouse generic methods report of Reference 9-3, and it is consistent with the guidelines provided in the Generic Letter 95-05 (Reference 9-1)□

In general, the methodology involves application of correlations for burst pressure, probability of leak 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. NDE uncertainties and uncertainties associated with burst pressure, leak rate probability and leak rate correlations are explicitly included by considering many thousands of voltage distributions through a Monte Carlo sampling process. The voltage distributions used in the projection analyses for the next operating cycle are obtained by applying growth data to the BOC distribution. The BOC voltage distributions include an adjustment for detection uncertainty and occurrence of new indications, in addition to the adjustments for NDE uncertainties. Comparisons of projected EOC voltage distributions with actual distributions after a cycle of operation have shown that the Monte Carlo analysis technique yields conservative estimates for EOC voltage distributions; therefore, leak and burst results based on those distributions are also conservative. Equation 3.5 in Reference 9-3 was used to determine the true BOC voltage.

7.0 Bobbin Voltage Distributions

This section describes the salient input data used to calculate EOC bobbin voltage distributions and presents results of calculations to project EOC-8 voltage distributions. Since a voltage-based repair criterion was not applied during the last cycle (Cycle 7), EOC-7 projections are not available and therefore a comparison of the actual measured and projected EOC-7 voltages cannot be made.

7.1 Calculation of Voltage Distributions

The analysis for EOC voltage distribution starts with a cycle initial voltage distribution, which is projected, to the end of cycle conditions applying growth appropriate for the anticipated cycle operating period. The number of indications assumed in the analysis to project EOC voltage distributions, and to perform tube leak rate and burst probability analyses, is obtained by adjusting the number of reported indications to account for detection uncertainty and initiation of new indications over the projection period. This is accomplished by using a POD factor, which is defined as the ratio of the actual number of indications detected to total number of indications present. A conservative value is assigned to POD based on historic data, and the value used herein is discussed in Section 7-2. The calculation of projected bobbin voltage frequency distribution is based on a net total number of indications returned to service, defined as follows.

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

where,

$N_{Tot\ RTS}$	=	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,
$N_{deplugged}$	=	Number of indications in tubes deplugged after the last cycle and returned to service in accordance with voltage-based repair criteria.

There are no deplugged tubes returned to service at BOC-8; therefore, $N_{deplugged} = 0$.

The methodology used in the projection of bobbin voltage frequency predictions is described in Reference 9-3. Salient input data used for projecting EOC-8 bobbin voltage frequency are further discussed below.

7.2 Probability of Detection (POD)

The Generic Letter 95-05 (Reference 9-1) requires the application of a constant POD value of 0.6 to define the BOC distribution for EOC voltage projections, unless an alternate POD is approved by the NRC. A POD value of 1.0 represents the ideal situation where all indications are detected. A voltage-dependent POD would yield a more accurate prediction of voltage distributions consistent with voltage-based repair criteria experience. In this report both NRC mandated constant POD of 0.6 as well as a voltage-dependent POD developed for EPRI

(POPCD) are used. The EPRI POPCD is developed by analyses of 18 inspections in 10 plants and is presented in Table 7-4 of Reference 9-4. The POPCD values represent a lower 95% confidence bound, and their distribution is presented in Table 7-1 and graphically illustrated in Figure 7-1.

7.3 Limiting Growth Rate Distribution

As discussed in Section 4.2, the NRC guidelines in Generic Letter 95-05 stipulate that the growth rate distribution(s) used in the SLB leak rate and tube probability analyses must contain at least 200 data points that are established using bobbin voltages measured in two consecutive inspections. Since Cycle 7 growth distribution is based on data from only 104 indications, it does not meet the above NRC requirement. In the absence of an acceptable plant-specific growth database, Generic Letter 95-05 requires the use of a bounding growth distribution established based on data available from similarly designed and operated plants. Prior to Comanche Peak Unit-1, a 1-volt repair criterion has been applied to 5 units with ¾" diameter tubes, and the growth data for these 5 units were used to establish a bounding growth distribution for ¾" plants. Details are provided in Section 4.2 and the bounding distribution is shown in Table 4-5. The CPDF values defining the bounding distribution are utilized to predict EOC-8 voltage distributions that are used in the SLB leak rate and tube burst analyses.

7.4 Cycle Operating Period

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

Cycle 7	- BOC-7 to EOC-7	- 510.4 EFPD or 1.40 EFPY (actual)
Cycle 8	- BOC-8 to EOC-8	- 496 EFPD or 1.36 EFPY (estimated)

7.5 Projected EOC-8 Voltage Distribution

Calculations for EOC-8 bobbin voltage projections were performed for all four SGs based on the EOC-7 voltage distributions. The BOC distributions were adjusted to account for probability of detection as described above, and the adjusted number of indications at BOC-8 are also shown in Table 7-2. Calculations were performed using a constant POD of 0.6 as well as the EPRI POPCD distribution (presented in Table 7-1). As discussed in Section 7-2, a bounding growth distribution for ¾" tube plants, shown in Table 4-5, was applied. The EOC-8 voltage distributions thus projected for all four SGs are summarized on Table 7-3. These results are also shown graphically on Figures 7-2 to 7-5. For the limiting SG, SG-4, the results based on a constant POD of 0.6 are more conservative than those using the voltage-dependent EPRI POPCD.

As discussed in Section 4.2, the growth rates utilized to project EOC-8 voltages are substantially higher than those observed during Cycle 7 (see Table 4-5 and Figure 4-4). There is no apparent reason to expect a substantially higher growth rate during Cycle 8 than during Cycle 7. Therefore, the peak voltages in the EOC-8 voltage distributions shown in Figures 7-2 to 7-5 are believed to be substantially overestimated.

Table 7-1
EPRI POPCD Distribution
Based on Data from 18 Inspections in 10 Plants

Voltage Bin	EPRI POPCD#
0.1	0.26
0.2	0.36
0.3	0.46
0.4	0.54
0.5	0.63
0.6	0.68
0.7	0.74
0.8	0.78
0.9	0.81
1	0.84
1.2	0.87
1.4	0.90
1.6	0.91
1.8	0.92
2	0.93
3	0.98
3.5	1.0

Data from Table 7-4 in Reference 9-4.

Table 7-2
Comanche Peak Unit 1 September 1999
EOC-7 Bobbin and Assumed BOC-8 Bobbin Distributions in SLB Leak Rate and Tube Burst Analyses

Voltage Bin	Steam Generator 1				Steam Generator 2			
	EOC - 7		BOC - 8		EOC - 7		BOC - 8	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.2	2	0	3.33	5.56	1	0	1.67	2.78
0.3	1	0	1.67	2.17	3	0	5.00	6.52
0.4	5	0	8.33	9.26	3	0	5.00	5.56
0.5	1	0	1.67	1.59	5	0	8.33	7.94
0.6	1	0	1.67	1.45	2	0	3.33	2.90
0.7	1	0	1.67	1.33	4	0	6.67	5.33
0.8	0	0	0.00	0.00	0	0	0.00	0.00
0.9	0	0	0	0	0	0	0.00	0.00
1	0	0	0	0	1	0	1.67	1.19
1.2	0	0	0	0	0	0	0.00	0.00
Total	11	0	18.33	21.36	19	0	31.67	32.21
> 1V	0	0	0	0	0	0	0	0

Voltage Bin	Steam Generator 3				Steam Generator 4			
	EOC - 7		BOC - 8		EOC - 7		BOC - 8	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.2	1	0	1.67	2.78	1	0	1.67	2.78
0.3	1	0	1.67	2.17	14	0	23.33	30.43
0.4	2	0	3.33	3.70	7	0	11.67	12.96
0.5	2	0	3.33	3.17	5	0	8.33	7.94
0.6	1	0	1.67	1.45	14	0	23.33	20.29
0.7	1	0	1.67	1.33	13	2	19.67	15.33
0.8	1	0	1.67	1.27	4	0	6.67	5.06
0.9	0	0	0	0	3	0	5.00	3.66
1	0	0	0	0	3	0	5.00	3.57
1.2	0	0	0	0	1	1	0.67	0.15
Total	9	0	15.00	15.88	65	3	105.33	102.18
> 1V	0	0	0	0	1	1	0.67	0.15

Table 7-3
Comanche Peak Unit 1 September 1999
Voltage Distribution Projection for EOC - 8

Voltage Bin	Steam Generator 1		Steam Generator 2		Steam Generator 3		Steam Generator 4	
	Projected Number of Indications at EOC - 8							
	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD
0.1	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
0.2	0.28	0.49	0.20	0.31	0.19	0.34	0.38	0.54
0.3	0.44	0.70	0.69	0.96	0.31	0.51	2.22	2.95
0.4	1.42	2.05	1.38	1.75	0.72	1.09	4.30	5.46
0.5	1.96	2.71	2.15	2.53	1.15	1.58	5.79	6.90
0.6	2.03	2.62	2.95	3.26	1.33	1.64	7.94	8.80
0.7	2.06	2.50	3.38	3.51	1.55	1.76	10.00	10.36
0.8	2.05	2.48	3.38	3.36	1.66	1.82	10.42	10.10
0.9	1.60	1.89	3.12	3.02	1.50	1.59	10.17	9.42
1.0	1.23	1.41	2.69	2.56	1.25	1.28	9.53	8.64
1.1	1.01	1.14	2.23	2.10	1.04	1.04	8.32	7.40
1.2	0.86	1.02	1.81	1.69	0.87	0.91	6.87	6.04
1.3	0.65	0.75	1.47	1.37	0.65	0.67	5.59	4.89
1.4	0.50	0.57	1.18	1.10	0.51	0.51	4.50	3.90
1.5	0.39	0.45	0.93	0.86	0.42	0.42	3.59	3.07
1.6	0.32	0.37	0.73	0.67	0.33	0.34	2.86	2.43
1.7	0.24	0.29	0.57	0.53	0.25	0.26	2.26	1.93
1.8	0.19	0.22	0.45	0.43	0.20	0.20	1.80	1.57
1.9	0.11	0.20	0.37	0.34	0.06	0.12	1.41	1.22
2.0	0.00	0.12	0.30	0.28	0.00	0.00	1.14	0.99
2.1	0.00	0.00	0.25	0.24	0.00	0.00	0.96	0.85
2.2	0.70	0.00	0.22	0.21	0.70	0.70	0.81	0.72
2.3	0.00	0.70	0.18	0.16	0.00	0.00	0.67	0.59
2.4	0.00	0.00	0.04	0.00	0.00	0.00	0.54	0.47
2.5	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.37
2.6	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.34
2.7	0.00	0.00	0.70	0.70	0.00	0.00	0.29	0.25
2.8	0.00	0.00	0.00	0.00	0.30	0.30	0.23	0.20
2.9	0.30	0.00	0.00	0.00			0.21	0.19
3.0		0.00	0.00	0.00			0.16	0.14
3.1		0.30	0.00	0.00			0.14	0.12
3.2			0.00	0.00			0.13	0.12
3.3			0.00	0.00			0.11	0.11
3.4			0.00	0.00			0.10	0.09
3.5			0.00	0.00			0.07	0.00
3.6			0.30	0.30			0.00	0.00
3.9							0.00	0.70
4.0							0.70	0.00
4.7							0.30	0.30
TOTAL	18.34	22.98	31.68	32.25	14.99	17.08	105.35	102.18
> 1 V	5.27	6.13	11.73	10.98	5.33	5.47	44.59	39.00
> 2 V	1.00	1.00	1.69	1.61	1.00	1.00	6.25	5.56

Figure 7-1
Generic POPCD Distribution Based on 18 Inspections in 10 Plants

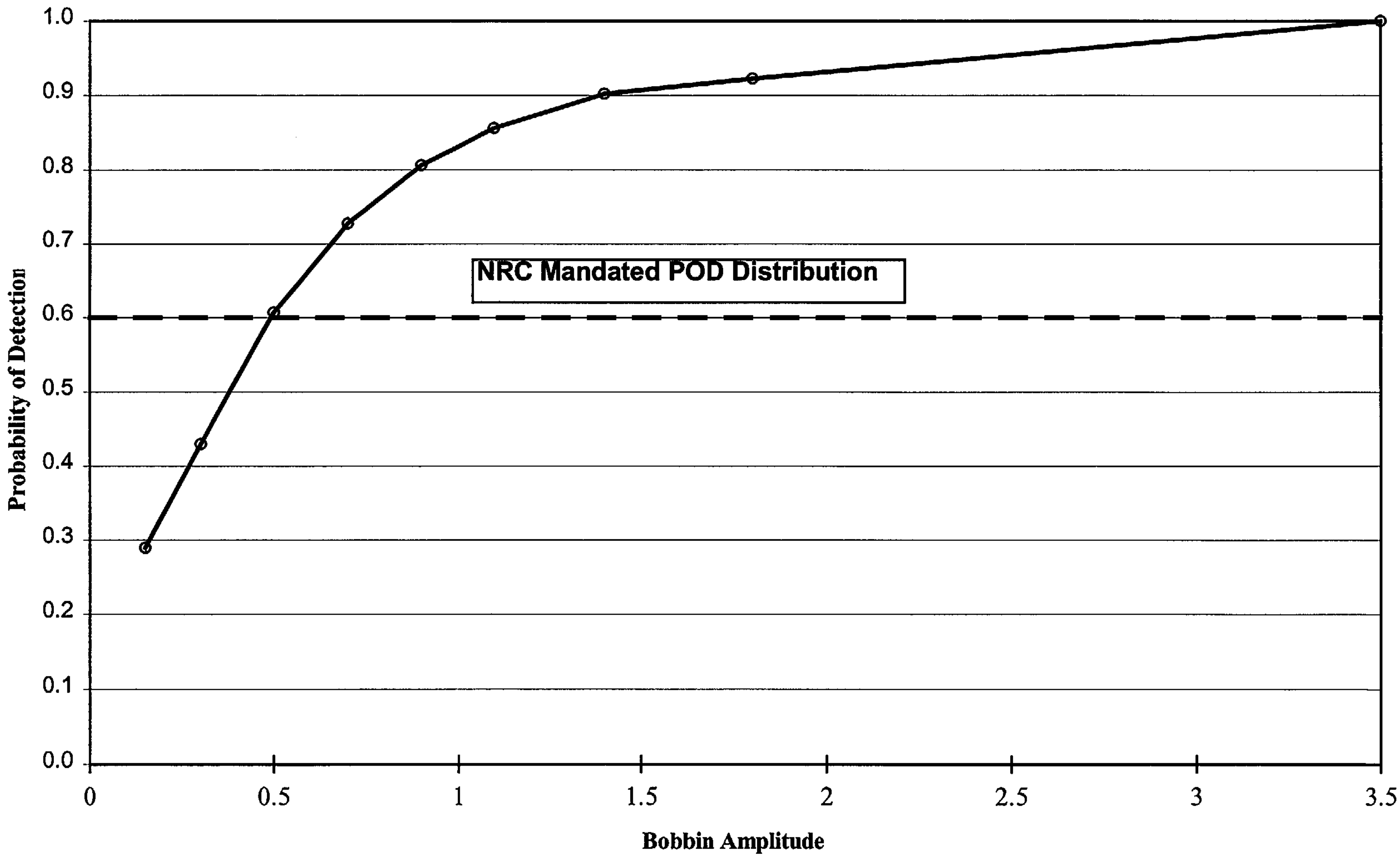
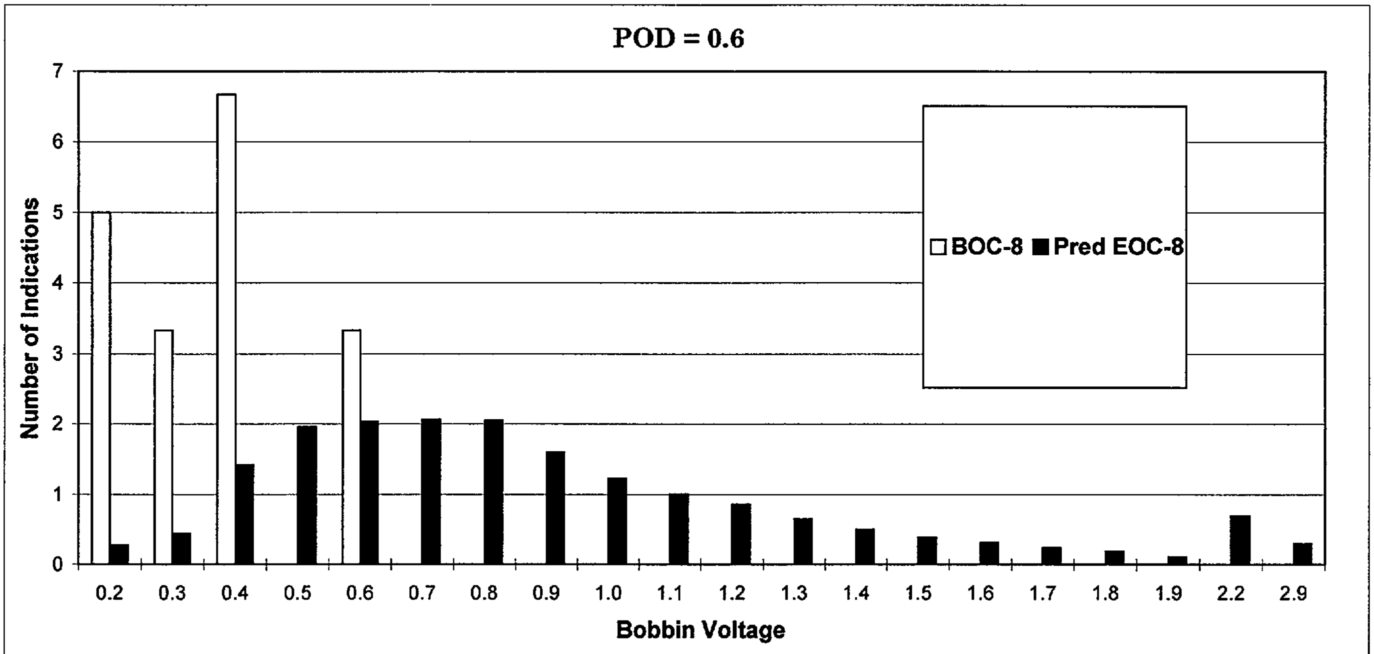


Figure 7-2
Comanche Peak Unit 1 SG-1
Predicted Bobbin Voltage Distribution for Cycle 8



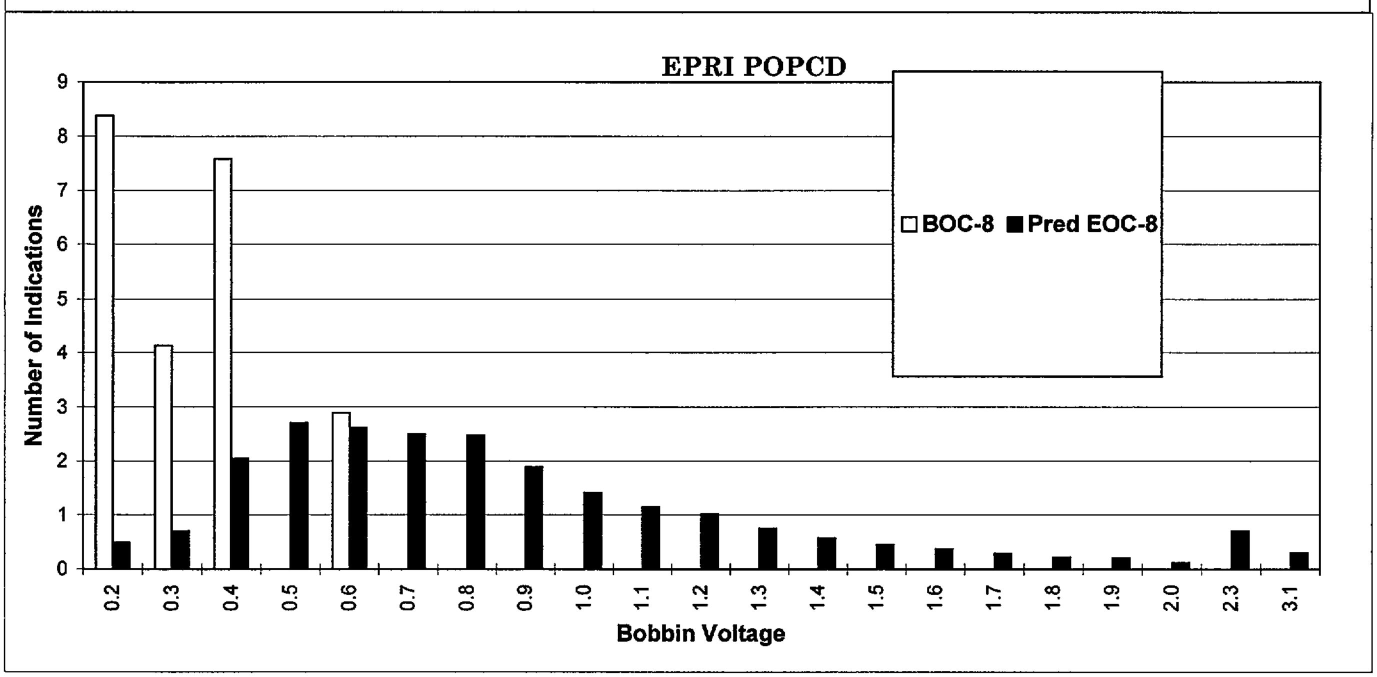
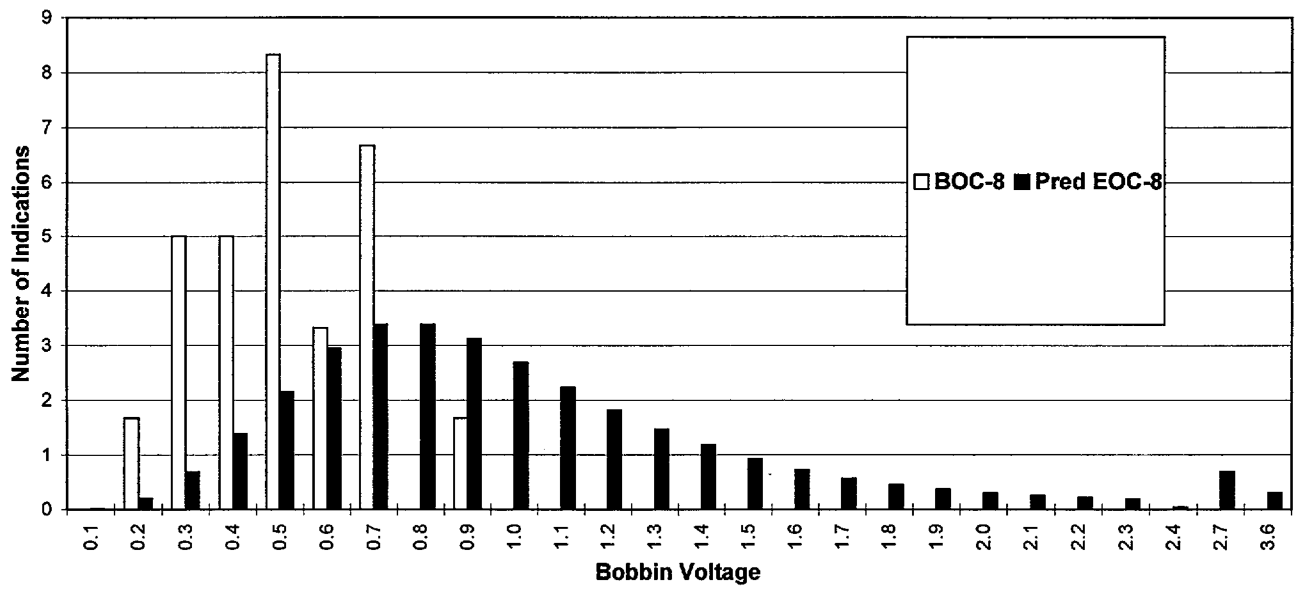


Figure 7-3
Comanche Peak Unit 1 SG-2
Predicted Bobbin Voltage Distribution for Cycle 8

POD = 0.6



EPRI POPCD

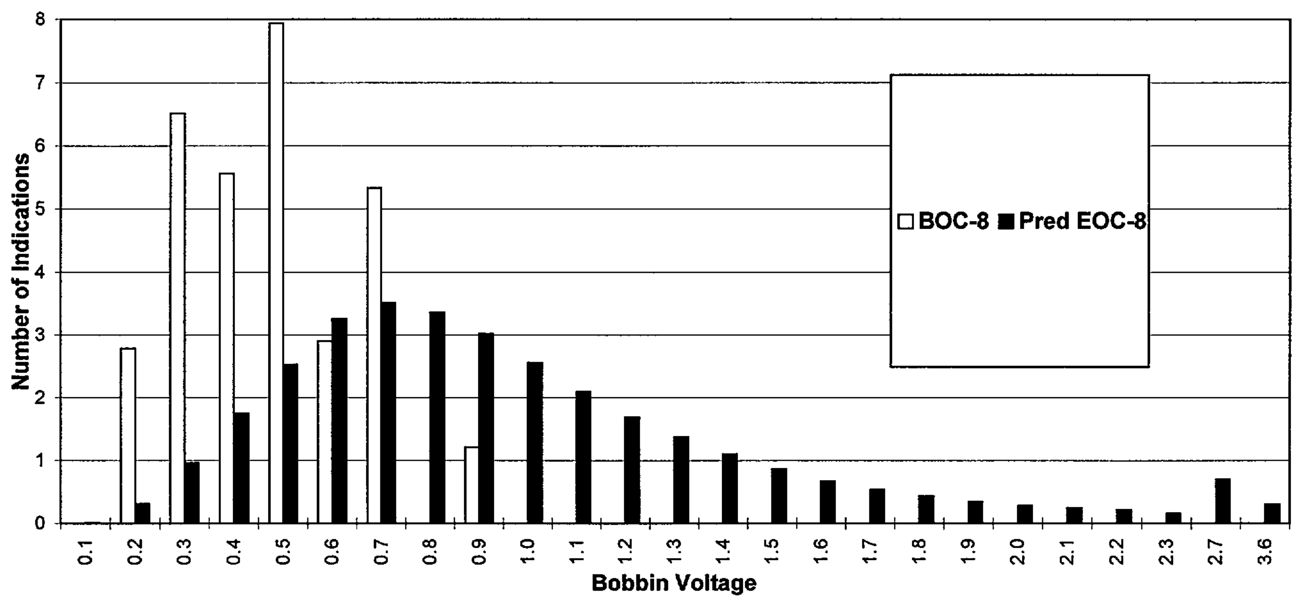
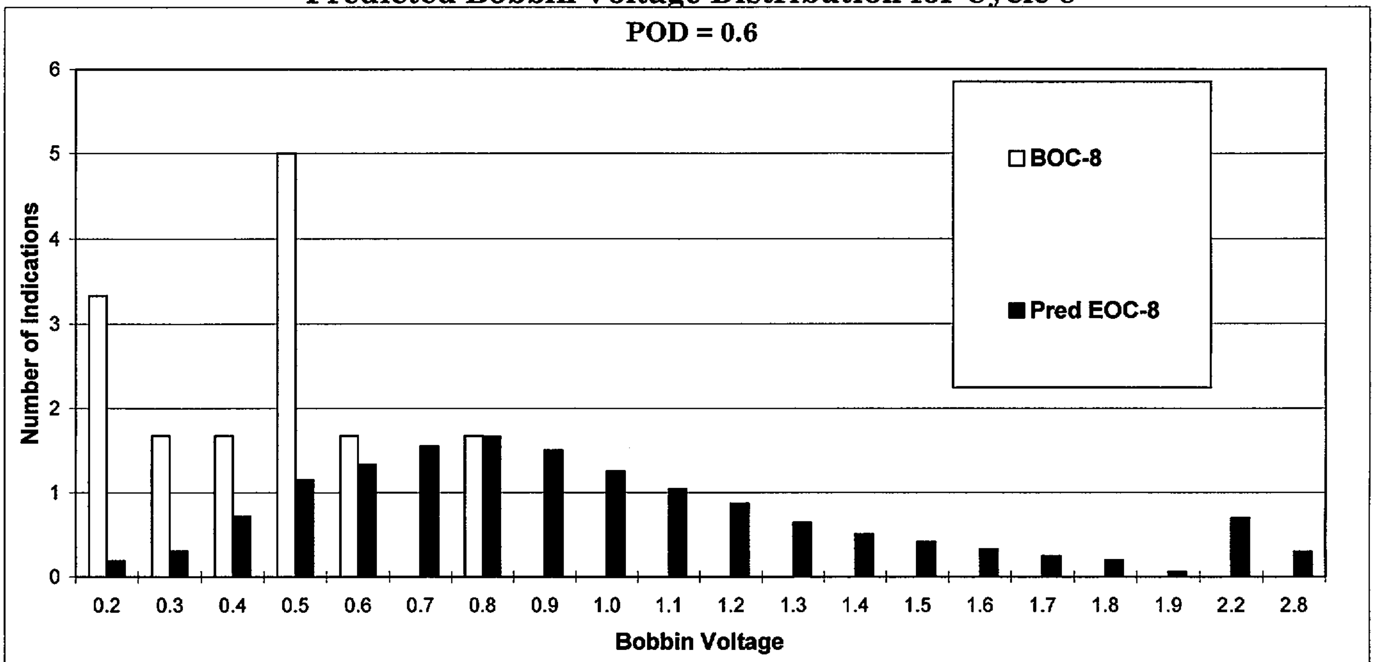


Figure 7-4
Comanche Peak Unit 1 SG-3
Predicted Bobbin Voltage Distribution for Cycle 8



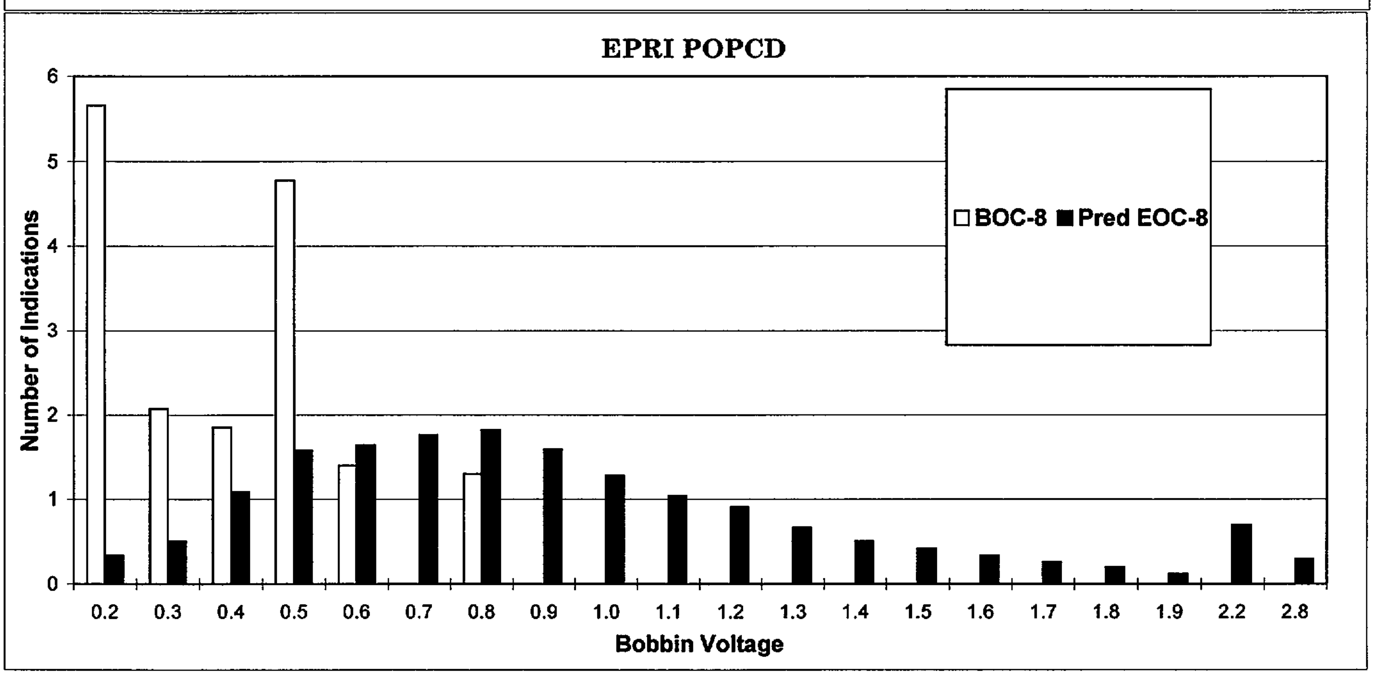
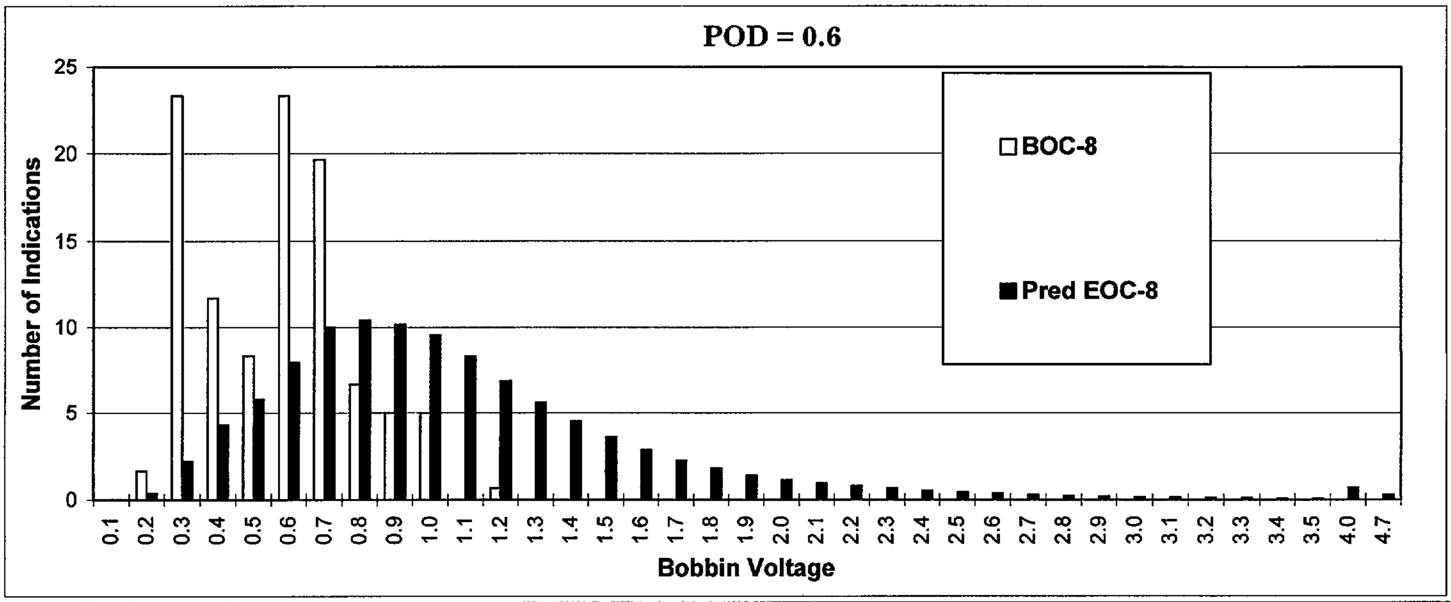
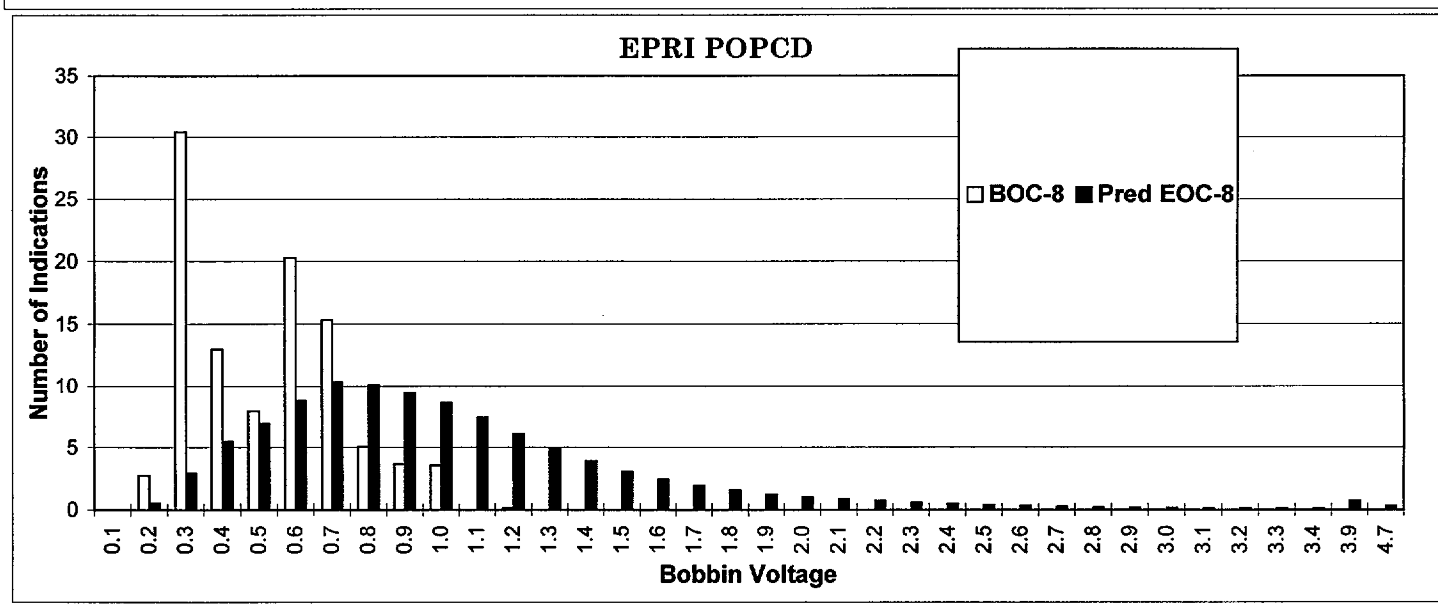


Figure 7-5
Comanche Peak Unit 1 SG-4
Predicted Bobbin Voltage Distribution for Cycle 8





8.0 SLB Leak Rate and Tube Burst Probability Analyses

This section presents the results of the analyses carried out to predict leak rates and tube burst probabilities for postulated SLB conditions using the actual voltage distributions from EOC-7 inspection (condition monitoring analysis) as well as the projected EOC-8 voltage distributions (operational assessment evaluation). The methodology used in these analyses is described in Section 6.0. SG-4 with the largest total number of indications is expected to yield the limiting SLB leak rate and burst probability for Cycle 8.

8.1 Leak Rate and Tube Burst Probability for EOC-7

About 63% of all the TSP ODSCC indications found in all 4 SGs (65 out of a total of 104) during the EOC-7 inspection were in SG-4, and hence the leak and burst analysis results based on the actual bobbin voltage distribution for SG-4 should bound those for the other 3 SGs. Therefore, the condition monitoring analysis was carried only for SG-4. The limiting SLB leak rate (1.4×10^{-4}) and tube burst probability (1.2×10^{-5}) values obtained using the actual EOC-7 conditions for SG-4 are relatively small, and they are 3 to 5 orders of magnitude below the corresponding acceptance limits (27.79 gpm at room temperature and 10^{-2}).

In summary, the condition monitoring analysis results meet the requirements of the Generic Letter 95-05.

8.2 Leak Rate and Tube Burst Probability for EOC-8

Calculations to predict SLB leak rates and tube burst probabilities for all 4 SGs in Comanche Peak Unit-1 at the EOC-8 conditions (operational assessment) were carried out using two values for POD: 1) NRC required constant value of 0.6, 2) voltage dependent EPRI POPCD distribution. The projected results for the EOC-8 conditions are summarized in Table 8-1. With the standard calculation methodology presented in Reference 9-3 and a constant POD of 0.6, the largest EOC-8 SLB leak rate projected is 0.14gpm (room temperature), and it is predicted for SG-4 which had the largest number of indications returned to service for Cycle 8 operation. This limiting SLB leak rate value is 2 orders of magnitude below the allowable SLB leakage limit for Cycle 8 of 27.79 gpm (room temperature). The highest tube burst probability, also predicted for SG-4, is 1.9×10^{-3}, and it is about 1/5th of the NRC reporting guideline of 10^{-2}.

When the EPRI POPCD distribution is used for POD, the total number of indications predicted are slightly higher than those for POD = 0.6 for SGs 1 to 3. The reason for this is that below about 0.5 volt the detection probability calculated from the EC inspection data could be significantly below 0.6 as shown by the EPRI POPCD distribution in Table 7-1 and Figure 7-1. Nearly 40 to 60% percent of the indications returned to service for Cycle 8 operations in SGs 1 to 3 are below 0.5 volt. The SLB leak rate and burst probability values based on EPRI POPCD for these SGs (with the exception of SG-2 leak rate and SG-3 burst probability) are also slightly higher those for POD=0.6.

As noted in Section 4.2, a bounding growth distribution based on the highest growth rates observed in 5 units with ¾" diameter tubes during cycles that utilized a 1 volt repair criterion was applied to project EOC-8 conditions. This bounding growth data is substantially higher than the actual growth during Cycle 7 (see Figure 4-4), and therefore the EOC-8 leak rate and burst probability estimates shown in Table 8-1 are believed to be very conservative.

Additional leak rate and tube burst pressure data are available from the tube specimens pulled during the recent inspection. An evaluation of the impact of the new data on the leak and burst correlations, described in Section 3.3, indicated that the new data do not significantly affect SLB tube burst probability and leak rate. In accordance with the NRC-NEI protocol for determining whether the voltage-based repair criteria leak and burst database should be updated to include the latest data, EOC-8 leak rate and tube burst probability calculations for the limiting SG (SG-4) were repeated using the correlations developed in Section 3.3 including the new data, and these results are also included in Table 8.1. While the SLB leak rate essentially remains the same, inclusion of the recent Comanche Peak Unit-1 pulled tube data in the leak and burst database increases tube burst probability from 1.9×10^{-3} to 2.3×10^{-3}. This increase in tube burst probability is negligible in comparison to the margin to the NRC reporting guideline of 10^{-2}. Thus, there is no immediate need to update the ¾" tube leak and burst database to include Comanche Peak Unit-1 pulled tube data.

In summary, SLB leak rates and tube burst probabilities predicted for EOC-8 are well below their respective limits.

{PRIVATE }Table 8-1
Comanche Peak Unit-1 September 1999 Outage
Summary of Projected Tube Leak Rate and Burst Probability
for EOC-8 - 250k Simulations

Steam Generator	POD	No. of Indic-ations[1]	Max. Volts[2]	Burst Probability		SLB Leak Rate (gpm)[3]	Comments
				1 Tube	1 or More Tubes		
EOC - 8 PROJECTIONS (Based on a projected Cycle 8 duration of 496 EFPD)							
1	0.6	18.3	2.9	3.5×10^{-4}	3.5×10^{-4}	1.5×10^{-2}	Standard leak rate d tube burst obability methodology Addendum-3 tabase
2		31.7	3.6	5.5×10^{-4}	5.5×10^{-4}	3.4×10^{-2}	
3		15.0	2.8	3.5×10^{-4}	3.5×10^{-4}	1.2×10^{-2}	
4		105.3	4.7	1.9×10^{-3}	1.9×10^{-3}	0.14	
4		105.3	4.7	2.3×10^{-3}	2.3×10^{-3}	0.14	Updated database with the present pulled tube data included
1	POPCD	23	3.1	4.2×10^{-4}	4.2×10^{-4}	1.9×10^{-2}	Standard leak rate d tube burst obability methodology Addendum-3 database
2		32.2	3.6	5.6×10^{-4}	5.6×10^{-4}	3.3×10^{-2}	
3		17.1	2.8	3.3×10^{-4}	3.3×10^{-4}	1.4×10^{-2}	
4		102.2	4.7	1.61×10^{-3}	1.6×10^{-3}	0.13	

Notes
(1) Number of indications adjusted for POD.
(2) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
(3) Equivalent volumetric rate at room temperature.

9.0 References

9-1 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.

9-2 NRC Letter "Comanche Peak Steam Electric Station (CPSES), Unit-1 – Issuance of Amendments Re: Implementation of the 1.0 Volt Steam Generator Tube Criteria (TAC Nos. MA 4843 and MA 4844," September 22, 1999.

9-3 WCAP-14277, Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections", Westinghouse Nuclear Services Division, December.1996.

9-4 EPRI Report NP 7480-L, Addendum 2, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate Repair Limits," Electric Power Research Institute, April 1998.

9-5 Letter from B. W. Sheron, Nuclear Regulatory Commission, to A. Marion, Nuclear Energy Institute, dated February 9, 1996.

9-6 EPRI Report NP 7480-L, Addendum 3, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate repair Limits," Electric Power Research Institute, May 1999.

9-7 SG-99-08-006, "Comanche Peak Steam Electric Station Unit 1, Steam Generator Degradation Assessment 1RF07 Refueling Outage," Westinghouse Electric Company, August 1999.