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PG&E Letter DCL-02-019

U.S. Nuclear Regulatory Commission
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Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Units 1 and 2
Response to NRC Request for Additional Information Regarding Supplement 3 to License Amendment Request 00-06, "Alternate Repair Criteria for Axial PWSCC at Dented Intersections in Steam Generator Tubing"

Dear Commissioners and Staff:

The NRC staff has identified additional information required in order to complete its evaluation associated with Supplement 3 to License Amendment Request (LAR) 00-06. LAR 00-06 proposes Technical Specification changes to incorporate alternate repair criteria for axial primary water stress corrosion cracking (PWSCC) at dented steam generator tube support plate locations. PG&E's response to the request for additional information is included in Enclosure 1.

This additional information does not affect the results of the safety evaluation and no significant hazards determination previously transmitted in PG&E Letter DCL-01-110, "Supplement 3 to License Amendment Request 00-06, 'Alternate Repair Criteria for Axial PWSCC at Dented Intersections is Steam Generator Tubing,'" dated November 13, 2001.

If you have any questions regarding this response, please contact Patrick Nugent at (805) 545-4720.

Sincerely,

Gregory M. Rueger
Senior Vice President - Generation and Chief Nuclear Officer

A001

kjs/4328
Enclosure
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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of PACIFIC GAS AND ELECTRIC COMPANY	)	Docket No. 50-275 Facility Operating License No. DPR-80
Diablo Canyon Power Plant Units 1 and 2	)	Docket No. 50-323 Facility Operating License No. DPR-82

AFFIDAVIT

Gregory M. Rueger, of lawful age, first being duly sworn upon oath says that he is Senior Vice President - Generation and Chief Nuclear Officer of Pacific Gas and Electric Company; that he has executed this response to the request for additional information on Supplement 3 to License Amendment Request 00-06 on behalf of said company with full power and authority to do so; that he is familiar with the content thereof; and that the facts stated therein are true and correct to the best of his knowledge, information, and belief.

Gregory M. Rueger
Senior Vice President – Generation
Chief Nuclear Officer

Subscribed and sworn to before me this 27th day of February 2002.
County of San Francisco
State of California

Amy Emiko Dong
Notary Public

AMY EMIKO DONG
Commission # 1206749
Notary Public - California
San Francisco County
My Comm. Expires Jan 2, 2003

PG&E Response to NRC Request for Additional Information Regarding Supplement 3 to License Amendment Request 00-06, "Alternate Repair Criteria for Axial PWSCC at Dented Intersections is Steam Generator Tubing"

Questions Related to Mixed Mode Indications

<u>Question 1.1</u>

The proposed method of establishing the separation distance to reach a null point recommends use of an 80-mil (high frequency) pancake coil operating at 600 kHz. The small diameter and high operating frequency of this coil is expected to provide the highest spatial resolution among all the coils on a standard 3-coil rotating probe. However, because there is the potential for the existence of mixed mode cracking of both ID and OD origin at the same dented TSP intersection, significant difference in sensitivity of such high-frequency coils to flaws of opposite origin may outweigh its superior resolution for the proposed application. The smaller depth of penetration at higher frequencies can lead to reduction of coil response to OD crack segments that may be present between mixed mode indications. Also, increased sensitivity to ID noise and tube diameter changes at higher frequencies can produce large signals that can distort the probe response from nearby flaws. Describe how the test matrix and testing addresses these concerns.

<u>PG&E Response to Question 1.1</u>

The mid-range Plus Point (+Point) coil is used for detection and identification that a mixed mode steam generator (SG) tube indication is present. The 80 millimeter (80-mil) coil is only used to assess whether null points exist between the axial and circumferential indications in order to determine if a detailed analysis of mixed mode effects is required. As summarized in Section 5.7 of WCAP 15573, Revision 1, "Depth-Based SG Tube Repair Criteria for Axial PWSCC at Dented TSP Intersections - Alternate Burst Pressure Calculation," dated October 2001, the indications must be very deep (such as >80% average depth) for mixed mode effects to occur, even for interacting indications. The second order effects of signal penetration, sensitivity to inner diameter (ID) noise and tube diameter changes at higher frequencies are small compared to the response of flaws greater than about 80% depth. The potential for a large ID signal to mask an outer diameter (OD) circumferential indication is very small. If the indications are physically separated, the lead-in response from the large ID signal would tend to lead to an underestimate of the separation between the axial and circumferential indications. If the indications are interacting, the signals from the circumferential flaw would be seen extending from the sides of the axial indication. A potential for masking requires that the circumferential response be centered on the axial response with an arc length no greater than the width of the axial response (about 40°). This type of masking would likely be called an intersecting mixed mode indication

in the +Point probe inspection, and there would be no need to evaluate the indication for separation distance.

The test matrix added noise typical of the range of noise levels found at the Diablo Canyon Power Plant (DCPP) SGs (Section 4.8.3 of WCAP 15573, Revision 1) and the effects of the noise additions were found to be small. The noise levels in the DCPP SGs are low compared to other original SGs. While this noise addition cannot represent all effects, the general lack of sensitivity to noise for the deep flaws required for mixed mode interactions supports the adequacy of the 80-mil coil for determination of adequate separation distances. In general, the presence of noise would make identification of the null points more difficult and thus add conservatism in determining adequate separation distances.

Question 1.2A

The topical report notes that ID/OD combinations for mixed mode indications were not included in the test matrix for two reasons; OD/OD specimens bound the ID/OD defects, and it is more difficult to maintain and verify adequate accuracy in the separation distance for ID/OD EDM notches. However, the staff notes that the presence of a null signal is dependent on the coil sensitivity and field spread. Thus, a null point, particularly at very high frequencies, may not always guarantee a minimum separation distance between ID/OD combinations of mixed mode flaws. This observation may negate the licensee's argument that OD/OD specimens bound the ID/OD defects. In light of the above concerns, provide further discussion supporting the decision not to use ID/OD flaw combinations.

PG&E Response to Question 1.2A

The presence of a null signal is dependent on the coil sensitivity and field spread. However, the implication that these effects are more dominant for ID/OD combinations compared to ID/ID or OD/OD is not clear. For the detection of null points, the requirement is to not detect a null point if adequate separation distance is not present. Low detection sensitivity could lead to a false null point call and lower sensitivity would occur for OD indications than for ID indications. If one of the indications is ID, the higher sensitivity would apply and the results for OD/OD indications would bound the potential for a false null point call. The lower sensitivity for OD circumferential indications led to the requirement for an increased null point separation distance (see response to Question 1.2B below) for OD indications compared to ID indications.

Question 1.2B

Although the use of deep EDM notches in clean tubes for establishing the upper limit for the coil lead-in/lead-out effect is a logical approach, it may not be a realistic simulation for the determination of mixed mode crack separation. Deep EDM notches produce high-amplitude signals that allow for clear identification of flaw extent, which is

not always the case for potentially tight or part-through wall cracks with low signal-to-noise ratio. Address this potential non-conservatism.

PG&E Response to Question 1.2B

As noted above in the response to question 1.1, the null point evaluation for separation distance is only used to determine the need for a detailed mixed mode evaluation. Since mixed mode effects are negligible for indications less than approximately 80 percent depth, confirmation of a separation distance for shallow flaws with low signal to noise ratios is not required since a mixed mode evaluation would not be necessary. In Section 4.8.4 of WCAP 15573, Revision 0 and Revision 1, it is shown that the smaller lead-in effects for deep cracks compared to electro discharge machining (EDM) notches is about 0.03 inch. In WCAP-15573, Revision 1, the required null point separation distances are increased to reflect differences between cracks and notches as well as between ID and OD circumferential indications. To define acceptable separation (Section 4.8.5 of WCAP-15573, Revision 1), an OD circumferential indication requires a null point length of about 0.075 inch (three null points for 0.025 inch pitch) and an ID circumferential indication requires a null point length of about 0.05 inch. The rotating pancake coil pitch, based upon rotation and translation speeds, is used rather than a direct nondestructive examination (NDE) measurement of distance. These increases in the null point requirements provide adequate compensation for the differences between cracks and EDM notches for the present application. Moreover, the alternate repair criteria (ARC) mixed mode evaluation requirements apply only to ID axial indications left in service by the ARC.

Question 1.3A

To obtain prototypic noise levels for the specimens, noise levels from Diablo Canyon intersections were electronically added to the NDE data for the laboratory specimens. However, a wide range of coherent sources of noise is present during field inspections (e.g., electronic noise, deposits, tube ID conditions, geometry, and wall thickness variations). Provide a discussion on the basis for the selection of noise used in the study and how it addresses all other potential noise sources.

PG&E Response to Question 1.3A

As described in Sections 4.9.2 and 4.9.3 of WCAP-15573, Revision 1, the noise used in the study was selected based upon the results of a sampling of the noise for the SGs at DCPP. +Point no detectable degradation intersections from all eight DCPP SGs were selected for noise evaluation. At least 15 intersections per SG for both units were evaluated (>120 total samples) with approximately even distribution of dent sizes < 2 volts, 2 to 5 volts and > 5 volts. Noise evaluations were performed for four 90 degree sectors at the highest axial noise level near the center of the plate and near the edge of the plate, as described in WCAP-15573, Revision 1. DCPP data determined to represent the lower, middle, and upper range of plant noise levels were added to each specimen for the evaluation.

The WCAP-15573, Revision 1, noise evaluation methodology addresses the noise in the plant inclusive of all of the sources mentioned in the question. The individual sources cannot easily be separated under field conditions and the values derived from the measurements are for the eddy current test system and tube conditions as a whole. Other sources of noise are typically parasitic in nature (e.g., slip ring noise and voltage spikes). These are evaluated in accordance with the data quality guidelines imposed during an inspection. The analyst, as the final arbiter of data quality, will reject data where parasitic noise interferes with the evaluation.

Question 1.3B

Because S/N (signal to noise) ratio is the governing parameter for detection of flaws, please discuss the basis for your decision not to include in the test matrix shallower flaws that are most affected by noise.

Response to Question 1.3B

As summarized in Section 5.7 of WCAP-15573, Revision 1, circumferential flaws ≤ 80 percent average depth have negligible mixed mode effects, even for interacting mixed mode indications with partial depth axial indications or throughwall axial indications of reasonably expected throughwall end of cycle lengths (< 0.25 inch). Since the primary purpose for the null point measurements is to determine the need for a detailed mixed mode evaluation when deep axial and circumferential indications are present, there was no need to include shallow flaws in the test matrix.

Question 1.4

Figure 4-28 in which vertical amplitude response from an axial through wall and an 80% OD EDM notch are compared shows the data at a frequency of 300 kHz. However, the proposed NDE method for determination of the separation distance between mixed mode cracks is based on analyzing the data at a frequency of 600 kHz. Therefore, please provide either this Figure displaying the data at a frequency of 600 kHz or a brief explanation of the difference in frequency.

PG&E Response to Question 1.4

Figure 2 of this letter provides the data of Figure 4-28 of WCAP-15573, Revision 1, displayed at a frequency of 600 kHz.

Questions Related to Assessment of Noise Levels

Question 2.1

Dents in all laboratory-produced specimens were created by setscrews at the center of the TSP. Field dents on the other hand are randomly scattered along the length of the

TSP. Detectability of flaws at TSP intersections is dependent on location, orientation, and origin of flaws. The maximum perturbation of coil response typically occurs at the edges of the TSP. As a result, describe how the laboratory produced specimens located at the center of the TSP simulate the limiting cases for the noise analyses.

Response to Question 2.1

For the bobbin coil, noise levels in small field dents ($\leq$ 2 volts) are typically higher at the edges of the SG tube support plate (TSP) as shown by the DCPP data in Section 4.9.3 of WCAP-15573, Revision 1. For the laboratory specimens, the localized denting and presence of the set screw led to higher noise levels at the center of the TSP than at the edge of the lab specimens. The noise levels at the center of the laboratory specimen dents are essentially the same as the edge of the DCPP support plates as shown in Section 4.9.3 of WCAP-15573, Revision 1. Thus, the influence of signal to noise on detectability for the center of the laboratory specimens corresponds to that at the edge of the field TSPs, and the laboratory specimens adequately represent detectability at the edges of the TSPs in the DCPP SGs. The laboratory noise levels are more conservative than that for potential flaws near the center of the DCPP SGs where most of the indications occur and the noise levels are less than that for the lab cracks.

For the +Point coil, noise levels at the edges of the TSP are not significantly different from the center of the TSP as shown by the DCPP data in Section 4.9.2 of WCAP-15573, Revision 1. The +Point coil noise levels for the laboratory samples at the center of the TSP are about twice that at either the center or the edge of the TSP at DCPP. Thus, the laboratory specimens are conservative relative to signal to noise for +Point coil detection. It is also shown in Section 4.8.4 and Figure 4-24 of WCAP-15573 Revision 1 that the measurement of null points for a mixed mode indication is not dependent upon the location of the circumferential indication within the TSP.

Question 2.2

Tabulated results on comparison of noise levels between field and the ARC database, in general, show higher noise levels (V_{pp} and V_{mx}) for the ARC database. However, no upper limit is established on S/N ratio values for the field application of the proposed NDE method. Discuss how you plan to ensure that the S/N ratio is acceptable for all tubes inspected in the field in the upcoming as well as future outage inspections if no limiting S/N ratio is established.

Response to Question 2.2

The sampling of field noise levels and establishing confidence levels on the noise levels as described in Section 4.9.2 of WCAP-15573, Revision 1, would generally bound the range of noise levels at DCPP. Since denting is essentially arrested in the DCPP SGs, the noise levels from this study can be expected to be applicable for one or more cycles. If noise levels were masking significant indications, new indications (not previously reported) potentially challenging tube integrity limits would be expected when

the signals are large enough to detect in a high noise level TSP intersection. No new indications challenging structural or leakage integrity have been found in the DCPP SGs. Section 7.12 of WCAP-15573, Revision 1, identifies analysis and reporting requirements in the event that large new indications are found in an inspection. Industry requirements on signal quality are currently being developed as part of updates to the Electric Power Research Institute (EPRI) inservice inspection (ISI) guidelines. When these requirements are finalized in a revision to the ISI guidelines, PG&E will implement the requirements for the DCPP SGs.

Question Related to Burst Pressure Analyses

Question 3.1

The Cochet/ASME model (used for condition monitoring) was shown to provide conservative estimates of the burst pressure of dented specimens. Since the ANL/EPRI model is generally less conservative than the Cochet/ASME model and was not developed with dented tube specimens, please confirm that the ANL/EPRI model gives realistic predictions for dented tubes.

Response to Question 3.1

It is not readily apparent that the Argonne National Laboratories/Electric Power Research Institute (ANL/EPRI) model is less conservative than the Cochet/American Society of Mechanical Engineers (Cochet/ASME) model given that the application of the latter involves correlating the model predictions to real tube behavior. The evolution of both of the models is based on the results of testing programs. The issue here is the effect that denting will have on the burst pressure of an exposed crack. As discussed in Table 7-1 of WCAP-15573, Revision 1, the probability that TSPs will displace in a steam line break (SLB) event given dented TSP intersections, resulting in exposure of a crack, is less than 0.001. Also, the evaluation is for primary water stress corrosion cracking (PWSCC) so the ligaments are on the outside surface of the tube. In order for the tube to burst, or the ligament to tear, from the loads caused by internal pressure, the material in the dent would have to be compressed in the hoop direction in order for the surface of the tube to be deformed or bulged in the radially outward direction. The "bulging factor" plays a large role in determining the strength of a cracked tube. This will add local strengthening to the cracked region since the dented geometry would reduce the magnitude of the tensile hoop stress at the crack tips. In addition, cold work associated with the deformation of the tube material could increase the resistance to tearing slightly. It may be more likely that the effects of the denting are secondary in nature and there would be no meaningful strengthening against burst. However, the contrary is that there would be no expected deleterious effect on the predictions associated with either model. An additional clarification question related to question 3.1 was received from the NRC Staff on February 6, 2002. A response to this additional clarification question related to question 3.1 will be provided in a subsequent submittal.

Questions Related to Monte Carlo Analysis

Question 4.1A

In Monte Carlo analysis, the reliability of the simulation can generally be increased by two measures: increasing the number of trials and/or reducing the sample variance. Sample variance can be reduced through various variance reduction techniques (VRTs) such as control variates, importance sampling, antithetic variates, etc. Since the reliability increases only with the square root of N, substantial increases in the sampling size are usually necessary to get modest increases in reliability. In addition, convergence to an acceptable reliability is frequently oscillatory due to the inherent noise in the statistical nature of a Monte Carlo simulation. As a result, a brute force effort (such as increasing the number of trials) is not generally employed solely on its own; rather, VRTs are used to accelerate the convergence. Reference to VRTs are made on page 5-12 of WCAP-15573 [Section 5.2.7]; however, no details were provided. Discuss how the reliability of the Monte Carlo simulations are assessed. Describe the VRTs employed, if any, in the Monte Carlo simulations? If no VRT is used (or if used only selectively), then provide a justification for not employing any VRT technique. If VRTs are used, provide the basis for the particular VRTs selected since not all VRTs lead to the same increases in reliability of the results. The basis may be in the form of a theoretical justification together with an explicit demonstration of the reduction of the standard deviation of the estimates. With the VRTs used, discuss whether the number of trials is optimal (see above).

Response to Question 4.1A

The reliability of the Monte Carlo simulations is assessed by comparing the results with similar simulations performed a greater number of times and with the results for similar problems performed with other simulation codes. There are only four variables being simulated for condition monitoring, the length and depth measurement errors, the regression relation error, and the material strength. For the operational assessment the growth of the indications is simulated as a fifth variable. The actual results are well behaved with regard to the input data, meaning that there are no singularities to worry about and that first derivative approximations to changes in the result with changes in the input variables are quite good for small differences in the input variables.

The reference to the use of variance reduction techniques (VRTs) appears in Section 5.2.7 of the WCAP-15573, Revision 1. The VRT employed was to perform a Latin-Hypercube simulation as described in “A Comparison of Three Methods for Selecting Values on Input Variables in the Analysis of Output from a Computer Code,” by McKay, M. D., et al., Technometrics, Vol. 21, No. 2, May, 1979. This is a stratified sampling technique in which the number of strata equals the number of simulations to be performed. The random value used is uniformly distributed within each stratum. Latin-Hypercube sampling is the limiting approach to stratified sampling.

Question 4.1B

Discuss how the optimum number of trials was determined. Various number of trials were reported in different parts of the reports, but the basis for the number of trials for each simulation (e.g., leakage and burst condition monitoring and operational assessment) was never discussed. Discuss whether the number of trials is optimal in terms of the required reliability (e.g., standard deviation of the estimate) and the given computational effort (measured by the time to complete the analysis) for each simulation.

Response to Question 4.1B

In general, the optimum number of trials is that number that is sufficient to characterize the probability of the event being investigated. The probability of the event being characterized for these analyses is 0.05 or 5 percent. The computational technique employed as part of the actual condition monitoring (CM) process is described in Section 5.2.3 of WCAP-15573, Revision 1. The number of simulations is stated in WCAP-15573, Revision 1, to be on the order of 5,000 to 10,000. The actual number used in practice is never less than 10,000. 10,000 simulations are sufficient given that the intent is to verify that the probability of burst is less than 0.05.

Section 5.2.7 of WCAP-15573, Revision 1, notes that the CM curves were developed using 1,000 simulations. These curves were developed to be illustrative of the process and to provide the engineer with a quick reference regarding the allowable depth and length combinations that would be needed to demonstrate acceptability. It is also noted that binomial statistics were used which did not account for the inclusion of the VRT in the analysis process. For example, Figure 5-8 of WCAP-15573, Revision 1, illustrates curves generated to represent 95 percent/95 percent burst acceptance limits. The depth is found for a given length such that the 39th ordered value of the burst pressure corresponds to the limit of interest. This corresponds to the value that would be selected if no VRT was being used. Since a VRT is being used, the value calculated is expected to be conservative.

Question 4.1C

Discuss the convergence analysis performed in the simulation. If "rules of thumb" are used to estimate the optimum number of trials, discuss the procedure and how its adequacy was confirmed (i.e., via convergence analysis).

Response to Question 4.1C

There are no convergence analyses performed within the Monte Carlo code itself. In other words, the code does not increase the number of simulations based on the rate of change of the predictions as a function of the number of simulation. Experience with this type of problem as it relates to the integrity of the SG tubes indicates that no such considerations are necessary. The problems being analyzed here are quite similar to

those associated with the outside diameter stress corrosion cracking (ODSCC) alternate repair criteria as discussed in the EPRI and Westinghouse supporting documents, and in NRC Generic Letter 95-05. The ODSCC ARC Monte Carlo techniques are described in WCAP-14277, Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections," dated January 1977, and were the subject of reviews by the NRC staff. A "rule of thumb" was formulated during the development of the methods used in the ODSCC program that the number of simulations needed was on the order of the inverse of the probability of occurrence of the event being described times $10^{1.5}$, i.e., about 30. The rule was derived from observations made at the time of the development of the ARC program regarding the rate of change of the estimates with increasing number of simulations. On a simpler scale, by the time about 30 occurrences of a low probability event occur in the simulations, say 30 of 10,000, the variation of the frequency of occurrence, (i.e., whether it is 28 or 32, etc., is not relatively great, ± 6 percent). If probability being sought was on the order of 0.003, the frequency of occurrence in 1,000 simulations could reasonably be expected to be on the order of 2 to 4, etc. The precision of the result would fluctuate by 3 ± 1 (± 33 percent).

Question 4.2

The quality of a Monte Carlo simulation is affected by the random number generation algorithms used. Discuss the algorithms employed (e.g., from Numerical Recipes). If non-standard algorithms are used, discuss how the quality of the random number generation algorithm was confirmed.

Response to Question 4.2

The random number generation algorithm is the "rnd2" function from the book "Numerical Recipes in FORTRAN the Art of Scientific Computing," by W. H. Press et al., Cambridge University Press, dated 1992, and is reported to provide near-perfect random numbers and has a period of $> 2 \cdot 10^{18}$. The maximum number of calls to the random number generator in performing the simulations is on the order of 10^9.

Question 4.3

In the Monte Carlo Analysis, P_B is considered a random variable taken from a population known to be normally distributed. As a result, "t" is assumed to follow the Student's t distribution (refer to equation 5-14 in Section 5.2.4 of WCAP-15573). However, in equation 5-12, P_B is given as the product of G_B, the normalized burst pressure, and S_F, the sum of the yield and ultimate stresses. G_B is log-normally distributed and S_F is normally distributed. As a result, the distribution of the product (i.e., P_B) does not have a simple algebraic form, but can be obtained numerically by direct Monte Carlo simulation. Since the distribution of P_B is not a normal distribution, provide the basis for treating "t", as defined in equation 5-14, as a random variable that follows the Student's t distribution. If the distribution of P_B is approximated with a bounding normal distribution, provide the justification and an assessment of the impact.

Response to Question 4.3

Section 5.2.4 of WCAP-15573, Revision 1, was written to discuss estimating the probability of burst for CM using deterministic analysis. It is noted in the discussion that the computations are being made for comparative purposes. The results of the analysis are illustrated on Figure 5-7 of WCAP-15573, Revision 1. The report also notes that for practical purposes the relation between the predicted and calculated values may be described as either linear-linear or log-log without much difference in the results, and that the linear-linear relationship was used for the development of the probability of burst estimates. A comparison of the cumulative distribution of the burst pressure for a representative value of the normalized burst pressure is illustrated in Figure 1 of this letter. It is apparent that the distributional characteristics are similar, and that the lower tail of the normal distribution is longer than that of the lognormal distribution. The difference in length between the two tails increases as the burst pressure decreases. Thus, using a normal distribution is conservative relative to using a lognormal distribution, i.e., the probability of low burst pressures will be estimated to be higher if the normal distribution is used for the calculations. In summary, comparative statistics, the value of 10^{-3} reported in Section 5.2.4 of WCAP-15573, Revision 1, for example, are estimated that are conservative relative to the problem at hand.

Questions Related to Accident Leakage Analysis

Question 5.1

The correlation parameters in equation 6.18 are given to 5 significant figures. Is this level of precision meaningful or necessary with respect to $Q_{CRACKFLO}$ and/or Q_{truth}?

Response to Question 5.1

The number of significant figures in equation 6.18 of WCAP-15573, Revision 1, is more than required for acceptable accuracy. The equation simply reflects the number of digits that were reported from the analysis and edited for the correlation and then used in applications of the correlation. There was no intent to indicate precision to five decimal places. At the same time there is no need to round the result to a smaller number of decimal places before using the correlation parameters in the simulation analyses since it does not affect the results of the analyses.

Question 5.2

The slope and intercept of equation 6.18 depend, in part, on the values assumed for roughness, tortuosity, crack length, crack depth, flow stress, and Young's modulus (i.e., they rely on tube and flaw specific values). Discuss how the variation of these properties are accounted for in the Monte Carlo leakage analysis method.

Response to Question 5.2

There is no need to include variations on roughness, etc., in the Monte Carlo analyses. The effects of uncertainties in these parameters are reflected in the uncertainty in the correlation of the calculation for the measured leak rates. The parameters used for all CRACKFLO code calculations are the same as included in the correlation for the leak rate uncertainties.

Question 5.3

Given that many of the parameters used in the leakage analysis are only nominally known, discuss how the necessary convergence and reliability of the Monte Carlo simulations is achieved. This relates to question 4.1C; however, it is repeated here for context.

Response to Question 5.3

The transformation from nominal information, (e.g., roughness, values to stochastic information) is achieved through the correlation of the measured leak rate to the predicted leak rates. The variation of leak rate for the PWSCC cracks is essentially no greater than that observed for ODSCC cracks. The large variation comes from variations from the nominal values of the variables and from the variation in leak rate associated with crack length, i.e., the leak rate is proportional to the 4^{th} power of the length. Therefore, a single significant ligament can bring about almost an order of magnitude change in the leak rate. These variations are accounted for in the Monte Carlo simulations. It is also worth noting that one of the observations from the ODSCC ARC programs was that the number of simulations needed to achieve relative stability in the predictions of the total leak rate was about a factor of five less than needed for the burst pressure. Because of the similar nature of the simulation problems, it would be expected that this phenomenon would continue to be evidenced for PWSCC predictions. Why this occurs was not studied in past programs, but may be due to the fact that the probability of leak is greater than the probability of burst. Therefore, the total leak rate likely comes from multiple leaking tubes, while the probability of burst is always associated with a single occurrence. Hence, a smaller event frequency is being quantified for burst than for leak rate. For additional information, see the response to questions 4.1A, 4.1B, and 4.1C.

Question Related to Probability of Detection (POD)

Question 6.1

In Sections 5.2.3 and 5.3.3 of WCAP 15573 Revision 0, a statement is made regarding the "creation of indications that are representative of missed indications based on the POD." Discuss how the POD corrections are made.

Response to Question 6.1

A constant POD = 0.6 is used for total SG analyses in support of WCAP-15573, Revision 1. This POD is accepted to be adequately conservative to encompass allowances for new indications (indications below detection levels) as well as a conservative estimate of undetected indications. Consequently, no additional provisions are included in the WCAP-15573, Revision 1, SG analyses to account for new indications.

A POD correction for undetected indications is only used in limited special cases as described in Section 7.12 of WCAP-15573, Revision 1. When applying the POD correction for undetected indications, the 1/POD factor applied to each indication can result in the prediction of the existence of fractional indications. For example, if the POD is 0.6 and 1 indication is found, the implication is that 1.7 indications were present and 0.7 of an indication was missed. This represents an average number of missed indications, where, for example, 30% of the time there was only one indication present and 70% of the time there were two indications present and only one of them was detected. While the Monte Carlo analysis is intended to provide only burst probabilities and total SLB leak rate distributions, the analysis can be performed carrying fractional indications or individual simulations can sample a uniform distribution between 0 and 1. In the latter case, if the sample between 0 and 1 is less than the fractional indication value, a whole indication is included in the analysis or the indication is omitted for that simulation. The sampling to obtain whole indications is used in codes supporting the ODSCC ARC for which burst probability and leakage are required. The indications generated by the 1/POD application are assumed to be the same size as the detected indication for which the POD correction is applied. The POD applied may be a constant value or dependent upon the NDE parameter used for the POD such as voltage or depth dependent.

The computer calculation code used to support the PWSCC ARC per WCAP-15573, Revision 1, includes additional capability as the code was also developed to determine the limiting indication burst pressure for comparison with structural requirements such as the SG differential pressure burst margin requirement. The use of one of the fractional indication approaches described above would be non-conservative due to the fractional weighting of the burst pressure distributions. That is, the samples not within the 1/POD fraction would have to be assumed to have a high burst pressure to develop a burst pressure distribution. It should be emphasized that the WCAP-15573, Revision 1, methodology does not use a total SG Monte Carlo analysis to develop a burst pressure distribution for comparing with structural margin requirements. The WCAP-15573, Revision 1, methods use a single indication Monte Carlo to determine if structural and leakage requirements are satisfied. The total SG Monte Carlo analysis is required only to obtain the total SLB leak rate. WCAP-15573, Revision 1, requires burst probability calculations in limited special case analyses as described in Section 7.12, but does not use the total SG analysis for comparison with deterministic burst margin requirements like the SG differential pressure burst margin requirement.

The following defines the steps applied in the PWSCC ARC code to obtain what are called POD groups for evaluations against the deterministic burst margin requirements. Note that the following reduces to the 0 to 1 sampling technique described above for influence on burst probability and leakage calculations, which are the only analyses required for WCAP-15573, Revision 1. Depth in these steps applies to average depth for burst analyses and maximum depth for leakage analyses.

- The indications found in the last inspection are ordered from largest depth down to smallest depth.
- The POD distribution is either interpolated to obtain the POD value at the depth of each indication or a constant POD = 0.6 is used as required for the WCAP-15573, Revision 1, analyses. When the uncertainties in the POD are included in the analysis, a POD distribution sample is obtained for each SG sample by sampling the POD uncertainties.
- For each indication, the number of indications initially present is obtained as 1/POD. If the detected indication is plugged, the number of indications remaining in service is 1/POD-1.
- If (1/POD-1) is greater than one, the whole number of indications is assigned to the beginning of cycle distribution for the indications being evaluated.
- The fractional values, that is, the portion of (1/POD-1) which is not a whole number, remain assigned to each indication. Then starting at the top, i.e., the deepest indications, the fractional values summing to 1.0 are identified and assigned to each indication group. In some cases, the fraction value for one indication may be split between two POD groups in order to obtain the 1.0 sum for each group. A POD group is a group of indications for which the fractional values sum to 1.0. The application of this process results in the 1st POD group having the deepest indications, the 2nd group follows in order, etc.
- Each indication with its defined crack profile then has its fraction of the POD group assigned in the range of 0 to 1. Then for each SG Monte Carlo sample, a random number between 0 and 1 is selected and used to select the indication in the POD group for the SG sample population. For the indication selected, the crack profile for the indication is included in the SG sample BOC distribution. Over many SG samples, each indication contributes to the SG according to its fraction of 1.0.
- When POD uncertainty is included in the analysis, the POD distribution can be different between each SG sample. In this case, the POD groups are reestablished for each SG sample and the random sample process described above is used to select the indication included in the SG sample BOC distribution.

The following is an example for the largest two detected indications, that are assumed to be left in service.

- Application of 1/POD for the first indication = 1.3. The whole indication is included in the analysis and the 0.3 fraction for this indication is assigned to POD Group 1.
- Application of 1/POD for the second indication = 1.8. The whole indication is included in the analysis, a 0.7 fraction for this indication is assigned to POD Group 1, bringing the total number of indicates in group 1 to 1.0, and the remaining 0.1 indication would be assigned to POD Group 2 to be included with lower depth indications in the analysis.
- For each Monte Carlo simulation, a random number between 0 and 1 is selected from a uniform distribution. If the random number is ≤ 0.3, the first indication is included to obtain a burst pressure for this simulation. If the random number is > 0.3, the second indication is included to obtain a burst pressure distribution for this simulation. The burst pressures over all simulations are combined to define the burst pressure distribution for POD Group 1. If the individual simulation burst pressure is less than the SLB pressure differential, the indication is counted as an SLB burst to develop a burst probability. Similarly, the leakage for each simulation sample is added to the total SG leakage to develop the total SG leak rate distribution. Thus, the method is the same for burst probability and leakage as that applied for the ODSCC ARC per GL 95-05. Again it is noted that the POD group burst pressure distributions are not used to satisfy any requirements of WCAP-15573, Revision 1.

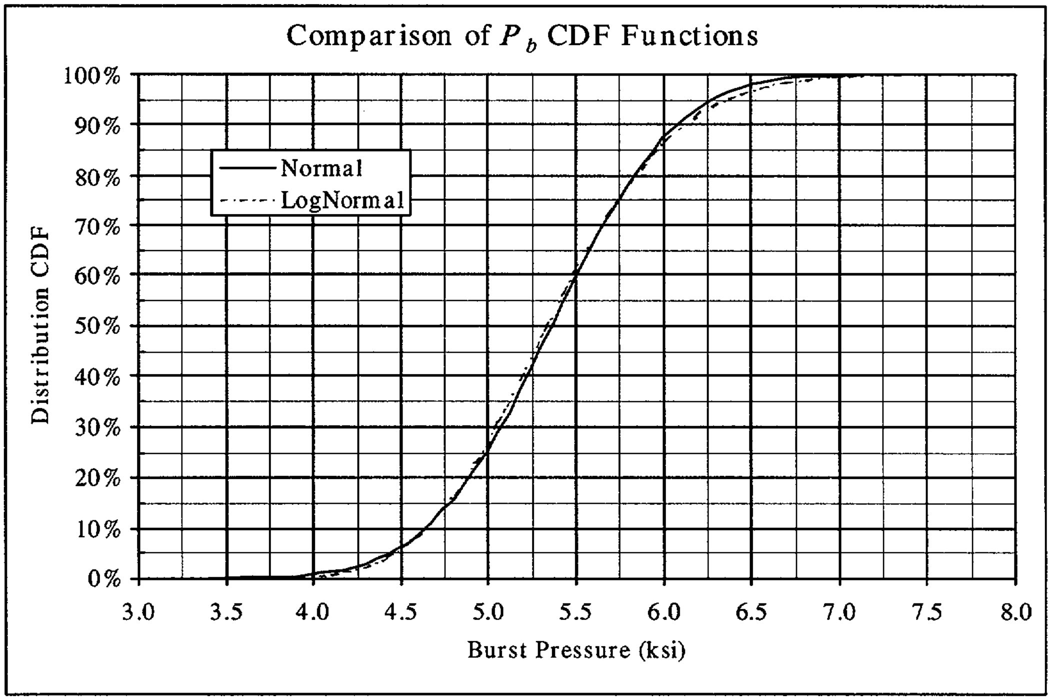
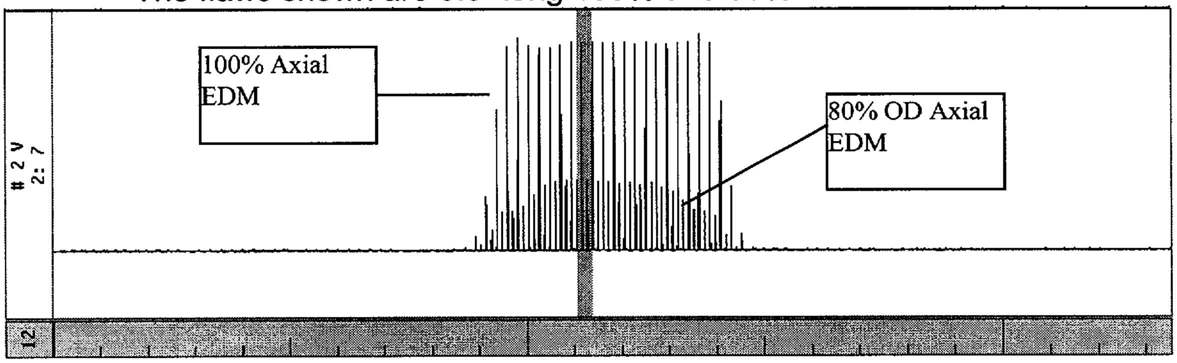
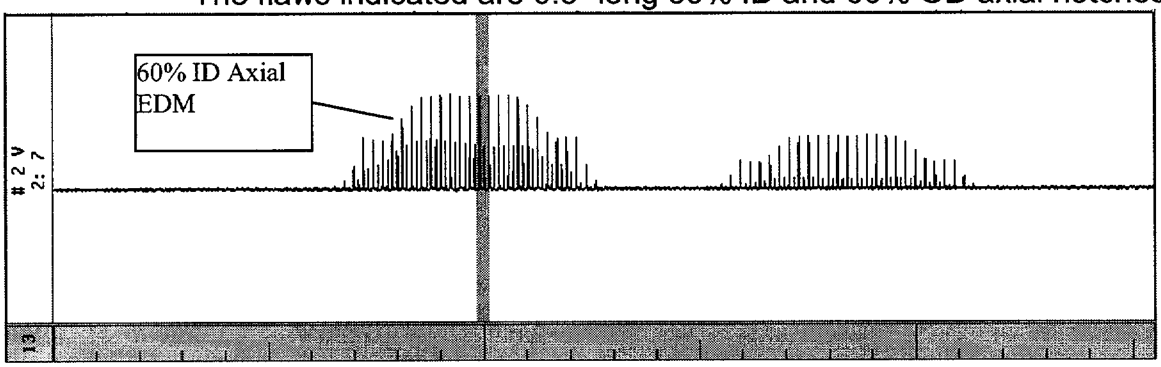


Figure 1: Representative CDF for Burst Pressure, G_m value of 0.035.

Vertical channel profile of Standard X-001-95
The flaws shown are 0.5" long 100% and 80% OD axial EDM notches



Vertical channel profile of Standard X-001-95
The flaws indicated are 0.5" long 60% ID and 60% OD axial notches



Vertical channel profile of Standard X-001-95
The flaw is a 0.5" long by 0.006" wide 100% circumferential EDM notch

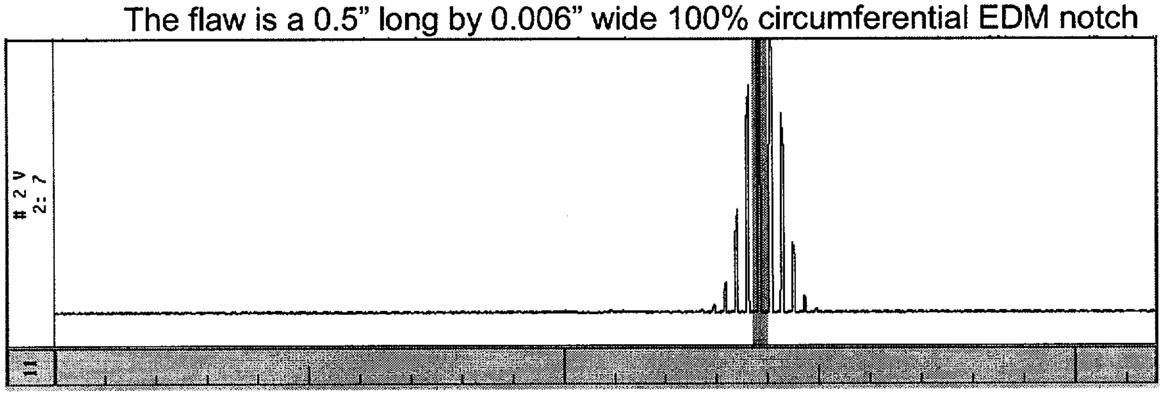


Figure 2. Pancake 80 mil Coil Vertical Amplitude Strip Charts for Axial and Circumferential EDM Notches.

Note: All data displayed is for a 0.080" shielded high frequency pancake at 600 kHz.