December 18, 1996

Mr. Kevin P. Donovan, Chairman
Boiling Water Reactor Owners' Group
Centerior Energy
Perry Power Plant
MC A210
P. O. Box 97
Perry, OH 44081

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON PROPOSED ALTERNATE BWR FEEDWATER NOZZLE INSPECTION REQUIREMENTS

Dear Mr. Donovan:

The staff is reviewing the BWR Owners' Group submittal, "Alternate BWR Feedwater Nozzle Inspection Requirements," dated October 30, 1996. This submittal provided recommendations for feedwater nozzle inspections that are intended as an alternative to those contained in NUREG-0619 based, in part, on advances made in ultrasonic techniques since 1980.

The staff concludes that additional information is needed before the staff can complete its review. Please provided a response to the attached request for additional information within 30 days of the receipt of this letter.

If you have any questions concerning this request, please contact the project manager, Jim Wilson, at (301) 415-1108.

Sincerely,

Original Signed By:

David B. Matthews, Chief
Generic Issues and Environmental Projects Branch
Office of Nuclear Reactor Regulation

Project No. 691

Attachment: as stated

cc: see attached list

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

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BWROG PROPOSED ALTERNATIVE TO NUREG-0619
REQUEST FOR ADDITIONAL INFORMATION

1. Implementation of NUREG-0619

Plants have used different methods (technical specification, commitment letter, procedures, etc) to implement the recommendations of NUREG-0619 into their inservice inspection (ISI) programs. The different implementation methods may result in individual safety evaluations. For each BWR plant, identify the method used for implementing NUREG-0619, and identify the mechanism that each plant would use for changing to the proposed alternatives.

2. Examination Volume

Earlier submittals on this subject sent to the NRC for review show the volume for ultrasonic examination (UT) starting inside the vessel at the vessel-to-nozzle blend (Zone 1) and ending past the safe end weld (Zone 5). The proposed alternative in GE-NE-523-A71-0594, Figures 4-1 and 4-2 show the volume for UT examination starting inside the vessel (Zone 1) and ending at the start of the outside diameter taper toward the safe end (Zone 3).

a. Describe the reason for the reduced examination volume and include any supporting data.

b. Identify any licensees that would be using an examination volume different than the proposed volume.

3. Crack Photographs and Descriptions

The efficacy of the proposed UT, as set forth in BWROG-95092 and Enclosures 1 and 2 (GE-NE-509-038-0394 Revision 1 and GE-NE-C3100016-02), depends on the orientation of cracking being primarily in planes that include the nozzle axis. The expectation of axial orientation is stated to be based on fracture mechanics analysis and field experience. The two photographs of nozzle cracking in NUREG-0619 show cracking in the blend radius that appears to be primarily perpendicular to the nozzle axis, and cracking in the bore that appears to be generally in a plane that includes the nozzle axis. Knowledge of the crack orientation is crucial to establishing the necessary parameters for UT inspection, which is very sensitive to crack orientation. Provide photographs or other descriptive data from inspections of inservice cracked nozzles from at least four different plants of different designs that show the actual crack orientations, and where the cracks were primarily located.

4. Control Rod Drive Return Line (CRDRL) Nozzles

The proposed alternative specifically excludes the CRDRL nozzle from consideration, stating that only two operating boiling water reactor (BWR) plants have active CRDRL nozzles.

ATTACHMENT

a. Describe special inspections, operating methods, or other considerations that are being used to reduce the thermal effects from the CRDRL.
b. Provide copies of the procedures that satisfy Section 8 of NUREG-0619 that are being followed at the two plants that do have active CRDRL nozzles.

5. Lack of Cracking

The recommendations of NUREG-0619 include dye penetrant (PT) examinations to detect new occurrences of cracking at feedwater nozzles. It is proposed in the submittal that new inspection procedures are justified in part on the belief that new incidents of cracking have not occurred since plant modifications were implemented in the late 1970's and early 1980's. However, it is evident from the submittal that PT examinations have been performed only to a limited extent due to difficult conditions of access and other practical limitations.

a. Describe the PT examinations that have been performed at specific plants, the extent and frequency of such examinations, and the effectiveness of such examinations to detect cracking for the different nozzle examination zones.

b. Describe the criteria being used for UT inspections to establish reliability and reproducibility of the UT techniques, and the independent methods used to verify the absence of cracking for each plant implementing the revised inspection approach as proposed in the submittal to justify that no nozzle cracking has reoccurred at the plants.

c. Discuss the UT criteria being used at each plant for determining recordable flaws/indications, i.e. 20% distance amplitude correction (DAC) curve and greater, 50% DAC curve and greater, etc.

e. For each BWR plant, provide a history and nozzle cracking status in a format similar to Tables 1 and 1a of this Attachment.

6. Sparger Design Integrity

In NUREG-0619, the cause of thermal fatigue cracking is assigned to leakage between the nozzles and spargers. A number of modifications to sparger designs to minimize bypass flow have been implemented with the potential for different leakage rates. Table 6-1 implies that these rates have been identified and can be expressed as multiplication factors.

a. Describe the types of inspections that have been performed to establish the long-term effectiveness of these different designs for minimize bypass flow rates and degradation of sealing capability. Provide actual experience, leakage rates, and acceptable leakage rates.

b. Provide justification for the different multiplication factors in Table 6-1.

7. Internal Ultrasonic Inspection of Clad Nozzles

For inspection of clad nozzles, there may be differences in sensitivity between UT applied on the internal and external surfaces. At least one licensee (Vermont Yankee) claims to have an internal UT inspection capable of inspecting clad nozzles.

a. Discuss the sensitivity aspects necessary to produce similar results for UT applied on the external and internal surfaces of cladded nozzle.

b. Explain why one or the other is preferable.

8. Inspection methods

The categorization of inspection methods given in Table 6-1 is simple, but not well adapted to the many variations of manual and automated inspection in current use in reactor inspections and to be expected in the near future. It does not take into account either the wide variety in available methodology (such as manual positioning, automated position recording, automated positioning, no data collection, threshold data collection, radio frequency (RF) data collection, video data collection, target motion analysis, phased array, and computer-aided design) or the many advantageous and disadvantageous characteristics associated with each (such as precise positioning, precise fixed beam direction, beam steering, operator discretion, thorough coverage, indication location, comparison with future inspections, detection ability, and sizing ability). The results from the Program for the Inspection of Steel Components (PISC) II and PISC III suggest that some manual inspectors perform better than the best automated systems, some manual inspectors perform worse than the worst automated systems, and the performance levels of different automated systems differ substantially. Based on the many variation and performance capabilities of the equipment, procedures, and personnel performing the inspections, describe the reasoning and supply the supporting justification for lumping the different inspection methods into manual and automated groupings in Table 6-1, include any standardized performance demonstrations that can be or were used for comparing the effectiveness of techniques and methods. The response to this concern may also apply to some of the following questions.

9. Inspection Interval by Method

The different multiplication factors for the different inspection methods in Table 6-1 imply that there is a probability of detecting flaws at different through-wall depths for the different inspection methods. The growth of these flaws would reach a given depth at different time intervals for the inspection methods. Provide data and/or analyses to support the factors in Table 6-1 for the different inspection methods.

10. Relative Performance of Automated RF and Phased Array Inspections

Phased array inspections provide a way of reducing misorientation angle by providing multiple skew and/or insonification angles during a single scan. In theory, then, a phased array inspection is inherently more sensitive than a

fixed-angle inspection. Explain why the two methods are considered equivalent in Table 6-1.

11. Relative Performance of Threshold, Linear RF, and Logarithmic RF

The detection sensitivities and positioning accuracies for automated threshold detection are no different than for full RF recording. The only difference between RF and logarithmic RF is whether there will be saturated signals. Some automated systems acquire logarithmic amplitude data without RF. Explain the justification for separating these methods in Table 6-1.

12. Inspection Schedule

Table 6-1 gives different multiplication factors that represent inspection time intervals. The submittal did not explain the rationale nor provide the supporting evidence for these factors. Provide an explanation for these different factors in terms of crack growth rates, detectability, probability of detection (POD), and any other relevant factors.

13. Alternative UT Inspection Techniques

The metal path for an examination on the ID conducted from the ID is short while the metal path for an examination on the ID conducted from the OD is long. The differences in metal path affects the POD and increases the errors for locating defects. Table 6-1 does not address the difference in difficulty between examination of the ID from the ID with examination of the ID from the OD. Explain why these techniques may be treated the same in Table 6-1 for the different methods.

14. Misorientation Angle Calculation - Statistics

In GE-NE-C3100016-02 Figures 4, 5, and 6, the data shows a trend in reflected signal amplitude. Signals from well-oriented notches are generally higher in amplitude than from poorly-oriented notches. However, the scatter in the data is so large that the POD for large misorientations is not predictable. The "best-fit lines" suggest that the data points for 30 to 40 degree misorientation angles are of average amplitudes. Conservatively, however, assuming that the same scatter exists for large misorientations as for small misorientations, they may be high-amplitude signals. In that case rather than using a best-fit line, a high-amplitude line may be drawn through the highest points and another line parallel to it through the lowest of the low-angle points. This second line would be the detectability line for low-amplitude reflections, and it will intersect the axis between 15 and 25 degrees, depending on notch depth. Using the 0.250" depth as a standard, the maximum acceptable misorientation angle would be 22 degrees.

Figure 1 of this Attachment (which contains the pair of graphs labeled "GE Figure 4" and "Distribution") shows some simple statistics that can be applied to the data of Figure 4 in GE-NE-C3100016-02. In the scatter graph in the upper part of Figure 1, the best-fit line has been shown, but then the lowest-amplitude fit line is also shown (subtracting the standard error of Y estimate from the regression output) and also the lowest-amplitude, minimum-slope fit

line (subtracting the standard error of coefficient from the slope of the best-fit line). The bar graph in the lower part of Figure 1 shows that the data are not normally distributed, which gives further reason to be conservative in interpretation.

a. Provide an analysis on the causes of scatter in the data (for example "alpha" insonficiation angle, frequency, transducer diameter, and bandwidth).

b. Provide additional data, if available, to improve statistics or explain scatter.

c. Provide a statistically defensible methodology for determining the maximum allowable misorientation angle.

15. Misorientation Angle - Relation to Amplitude

It is not clear why there should be a linear relationship between misorientation and log-amplitude, as implied by the use of a linear best-fit curve in Figures 4-6 of GE-NE-C3100016-02. For example, fitting a negative exponential curve to the data improves the R-squared from 0.5 to 0.7 (Figure 2 to this Attachment). This is not to suggest that the amplitude is actually a double power function, but just to emphasize that more work is needed to give either theoretical or experimental assurance that certain large misorientations will not result in underinspection. According to Kratukramer (*Ultrasonic Testing of Materials*, 1983, p.66) the amplitude as a function of angle for a circular object is given by a Bessel function composed with a sine function. For long cracks, minima can be expected for certain misorientation angles, which means that, for example, for a certain setup, misorientation angles of 20 degrees and 30 degrees might both give adequate reflections, while a misorientation of 25 degrees might give no reflection at all. In addition, as the misorientation angle grows large, the diffraction is probably from the edge of the crack, and not from the crack face, in which case misorientation has very little effect, since crack edges diffract in nearly cylindrical or spherical patterns. This may be one reason that the negative exponential appears to fit the data better, as it may be that for very large misorientations, it is the edge of the defect that is being detected. Discuss the theoretical treatment of the misorientation angle and provide a POD (which should be something on the order of 90/95) for misoriented insonifications that do not exceed the maximum allowable misorientation angle. The treatment of this does not need to be with specific reference to nozzle geometries, but any inspection using comparable essential ultrasonic variables.

16. Misorientation Angle Calculation - Theory and Experiment

The reception of echoes from misoriented flaws is due to diffraction effects. These effects are strongly dependent on frequency, bandwidth, transducer size, and crack dimensions and shape. All else being equal, longer cracks will be more directive than smaller ones; i.e., the allowable misorientation angle for a long crack will be less than for a short one. Also, the directivity of rectangular artificial flaws, circular artificial flaws, and irregular cracks will be different.

a. Provide theoretical or experimental results (which could include computer simulations and literature citations) to support extrapolation, using the set of known signals from artificial defects, to expected signals from actual flaws. Experimental results need not be from nozzle geometries.

b. Provide a methodology to establish a set of worst-case artificial flaws and to define inspection procedures, including allowable ranges of essential variables, based on that worst-case set. Use of analytical approximations, literature citations, and/or commercial models such as the Weidlinger Associates WARay3D would be acceptable tools for this purpose.

17. Misorientation Results from Cracks

The only crack data sets shown in GE-NE-C3100016-02 are from cracks at 0 degree misorientation. Provide and discuss data from cracks at various misorientation angles (at least two cracks each at three medium to large angles, say 10 and 20 degrees), to demonstrate that the misorientation results are not due to the characteristics of the EDM notches. This work could be done in planar thick sections, not necessarily on a nozzle mockup.

18. Comparison of Notch and Crack Amplitudes

The average amplitude for the 0.150 inch notch detections using Z1V and Z1R is about 30 dB. The average amplitude for the 0.150 inch crack detections using Z1V and Z1R is about 23 dB. Discuss the implications for maximum allowable misorientation angle and POD, given the wide spread in notch and crack responses, the 7 dB signal loss, and the noise level of the material.

19. Grind-out Noise Considerations

In GENE-955-002-0195, modeling and demonstration of UT of grindouts is addressed. The modeling indicates that surface orientations of grindouts are not likely to cause a problem. However, the noise from the grinding marks makes flaw detection marginal. The report states that EDM notches were detected at +12 dB relative to the grinding noise. It does not specify how large the notches were; however, crack response is typically 6 to 10 dB less than notch response for comparable sizes (although Table 3 of GENE-955-002-0195 shows an example of higher as well as lower crack response), which means crack detection may be marginal. Given that grindouts are by definition locations of potential crack growth, that detection of cracks in grindouts may be marginal, and that comparison of before and after cracking is much more sensitive than first-time detection, discuss the use of an initial inspection baseline for grindouts and subsequent comparison to the baseline during later inspections.

20. Grind-out Geometry Considerations

Apart from the question of noise, the geometry of the grindout can affect the reflected signals (although not the tip-diffracted signals). If the crack propagates normal to the nozzle surface (A in Figure 3 of this Attachment),

then the corner trap amplitude is reduced from both clockwise (CW) and counter clockwise (CCW) directions. If the crack propagates normal to the grindout surface (B), then the amplitude may be reduced from the CW direction but maintained or enhanced from the CCW direction.

a. Provide and discuss data or fracture mechanics analysis to indicate which situation is more likely to occur, and whether this is substantially different from regions without a grindout.

b. Discuss estimates of the reduction in indication amplitude.

21. Crack Growth by Stress Corrosion

Growth of nozzle region cracks can be driven by stress corrosion cracking in addition to fatigue cycles. Recent evaluations have addressed crack growth by stress corrosion cracking the beltline of BWR reactor vessels ("BWR Vessel and Internals Project, BWR Reactor Pressure Vessel Shell Weld Inspection Recommendations (BWRVIP-05)," EPRI TR-105697, September 1995).

a. Provide calculations that show how the data on stress corrosion crack growth rates from BWRVIP-05 modify the fracture mechanic results of NEDE-21821-A.

b. Discuss the impact of these calculations on the conclusions of the current submittal regarding the growth of 0.25-inch deep cracks.

22. Crack Growth by Fatigue

The crack growth calculations of NEDE-21821-A were based on low alloy steel fatigue crack growth data available in the 1980 time frame as indicated in Figure 4-137. Since 1980 additional crack data have been generated, and improved predictive equations (e.g. Figure A-4300-2 of ASME Section XI) have been developed.

a. Provide calculations that show how the current data on crack growth rates would modify the fracture mechanics results of NEDE-21821-A.

b. Discuss the impact of these calculations on the conclusions of the current submittal regarding the growth of 0.25-inch deep cracks.

23. Effects of Corrective Action on Crack Initiation

The submittal addresses plant specific evaluations for the growth of nozzle cracks with an initial depth of 0.25 inch, but does not include evaluations that address the effectiveness of plant-specific corrective actions to prevent crack initiation. Since the growth of cracks from a 0.25-inch initial depth is not influenced by the high cycle thermal stresses associated with bypass flow at the sparger thermal sleeves, there appears to be no discrimination in the proposed inspection approach between plants that have implemented all the recommendations of NUREG-0619 to prevent crack initiation (clad removal, leakage monitoring, etc.) and other plants that have a much higher potential for the reoccurrence of cracking. Provide clarification regarding appropriate

limitations on implementing the proposed inspection approach at plants with minimal corrective actions to mitigate thermal fatigue cracking, and/or provide a rationale for a common inspection approach for plants with significantly different potentials for the initiation of thermal fatigue cracks.

24. Fracture mechanics Calculations for all BWR Plants

The submittal (page 5-1) states that 11 of 20 plants provided results of fracture mechanics evaluations based on the current plant operational practices. These calculations were presented to support a generic change to ISI requirements. Additional information is requested regarding calculations for the other 9 plants, either as plant specific fracture mechanics evaluations or as information showing that the conditions for each of these 9 plants are bounded by the crack growth calculations for the other 11 plants.

25. Crack Depths in Clad Nozzles

BWROG submittal Section 4.3 and ASME Section XI account only for the flaw depth as measured from the clad-base metal interface. The appropriate flaw depth for use in fracture mechanic calculations is the total crack depth including the cladding.

a. Explain the reasoning for accounting only for the flaw depth as measured from the clad-base metal interface, and provide calculations showing that this leads to acceptable results.

b. If the flaw depth is measured from the inner cladded surface, is it acceptable to use a nominal clad thickness, or is it necessary to measure the actual clad thickness? Provide calculations to support the answer.

Table 1 - Suggested format for reporting history and status of BWR plant nozzle cracking

Item Plant name	Reportable Nozzle Cracking Observed	Cladding Removed	Grindouts Performed	Sparger Modified	PT Performed	VT Performed	UT Performed	Other Status Items
	Yes No Latest Date	Yes No Date	Yes No Latest Date	Yes No Date Modification: Interference Piston Ring Triple Sleeve etc.	Yes No Latest Date Extent Cracking Yes No	Yes No Latest Date Extent Cracking Yes No	Yes No Latest Date Method Used: Manual Automated RF Recorded Phased Array Cracking Yes No	
Site 1 Plant 1 Nozzle 1 Nozzle 2 ... (or: All Nozzles)								

Table 1 - Suggested format for reporting history and status of BWR plant nozzle cracking (cont'd)

Site 1 Plant 2 Nozzle 1 Nozzle 2 ... (or: All Nozzles)								
...								
Site 2 Plant 1 ...								
Site 2 Plant 2 ...								
...								
Item Plant name	Reportable Nozzle Cracking Observed	Cladding Removed	Grindouts Performed	Sparger Modified	PT Performed	VT Performed	UT Performed	Other Status Items

Table 1a - NUREG-0619 data plus additional notes

Item Plant name	Reportable Nozzle Cracking Observed	Cladding Removed	Grindouts Performed	Sparger Modified	PT Performed	VT Performed	UT Performed	Other Status Items
	Yes/No Latest Date	Yes/No Date	Yes/No Latest Date	Yes/No Date Modification: Interference Piston Ring Triple Sleeve etc.	Yes/No Latest Date Extent Cracking Yes/No	Yes/No Latest Date Extent Cracking Yes/No	Yes/No Latest Date Method Used: Manual Automated RF Recorded Phased Array Cracking Yes/No	
Nine Mile Point 1	Y			Y-4				Remachine 4 nozzles
Humboldt Bay	Y			Y-1				Remachine nozzle
Pilgrim	Y	Y	Y	Y, 2-ring 3-sleeve				
Millstone 1	Y		Y	Y				
Dresden 2	Y		Y	Y				

Table 1a - NUREG-0619 data plus additional notes (continued)

Monticello	Y	Y	Y	Y, single ring + sleeve				
Oyster Creek	Y			Y-4				Remachine 4 nozzles
Quad Cities 1	Y	Y 1994	Y	Y, 2-ring 3-sleeve 1994				Leakage monitors 1994
Dresden 3	Y		Y	Y, 2-ring 3-sleeve 1994				Leakage monitors 1994
Peach Bottom 2	Y	Y	Y	Y, 2-ring 3-sleeve				
Quad Cities 2	Y	Y	Y	Y, 2-ring 3-sleeve				
Vermont Yankee	Y		Y	Y			1995, ID	
Cooper		Y	Y	Y, 2-ring 3-sleeve			1991	Leakage monitor 1994
Browns Ferry 1		Y	Y	Y, single ring + sleeve				
Edwin I. Hatch 1		Y	Y	Y, 2-ring 3-sleeve			1994	
Peach Bottom 3			Y					

Table 1a - NUREG-0619 data plus additional notes (continued)

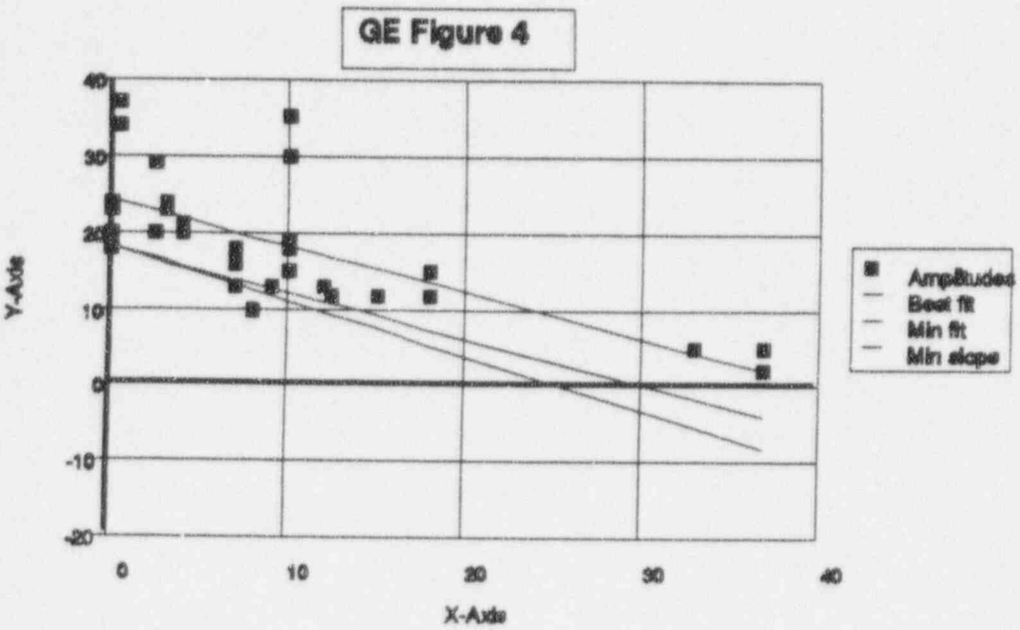
Browns Ferry 2		Y		Y, 2-ring 3-sleeve				
Browns Ferry 3		Y		Y, 2-ring 3-sleeve				
Duane Arnold								welded sleeve
James A. Fitzpatrick		Y		Y, 2-ring 3-sleeve		1995	1995	leakage monitor (thermo-couple) 1994
Brunswick 2		N		Y, Interference				
Edwin I. Hatch 2							1994	
Item Plant name	Reportable Nozzle Cracking Observed	Cladding Removed	Grindouts Performed	Sparger Modified	PT Performed	VT Performed	UT Performed	Other Status Items

Notes:

Plants are listed in decreasing order of maximum crack size, according to NUREG-0619 data.

Reportable Cracking means depth of 0.25" or more.

Abbreviations: PT = Penetrant Testing; VT = Visual Testing; UT = Ultrasonic Testing



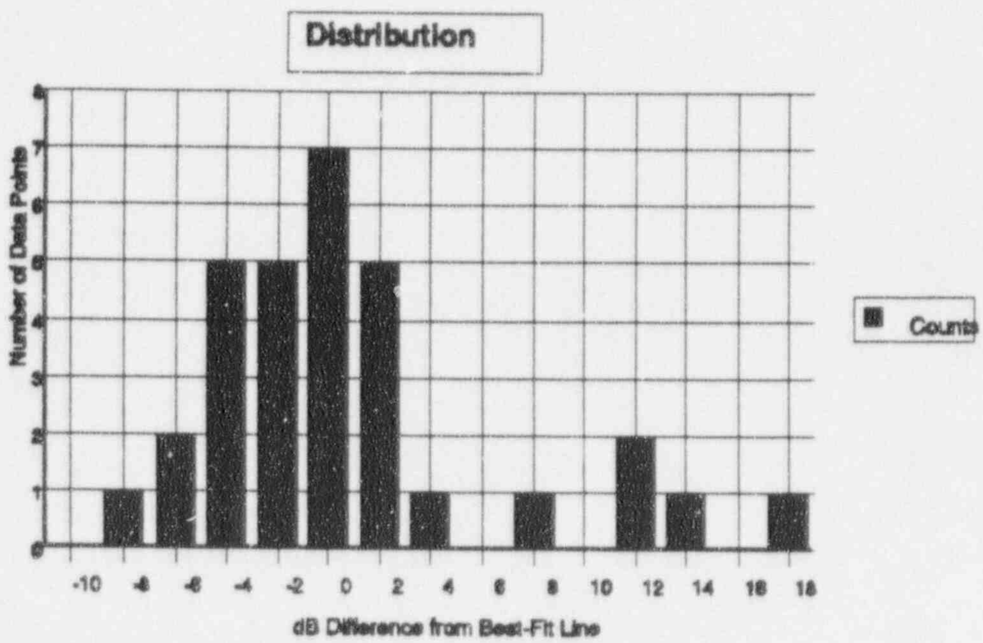
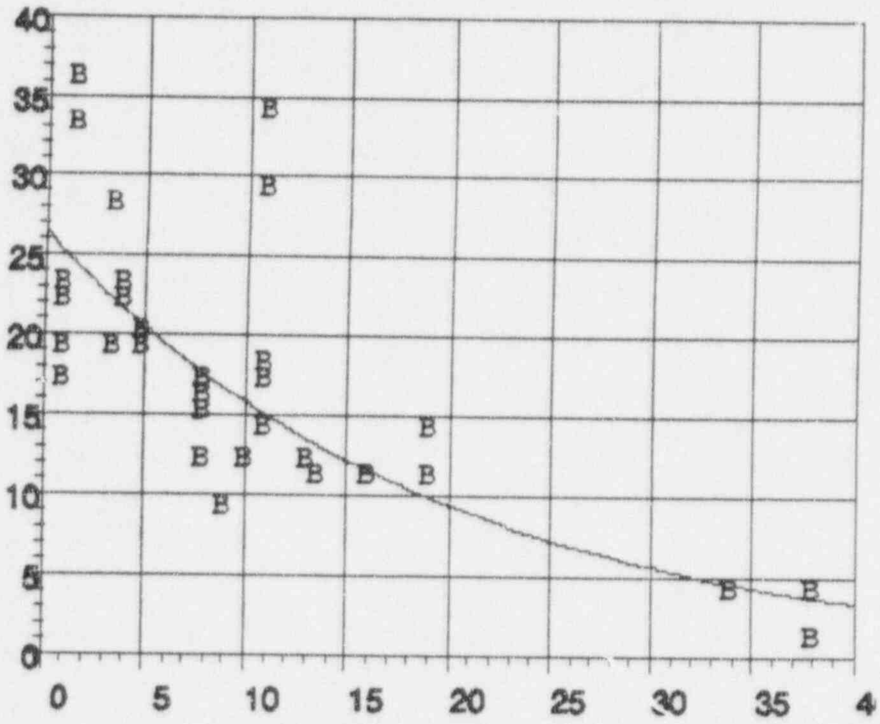


Figure 1. Analysis of GE Figure 4 data (approximate)

Exponential fit to GE Figure 4 data



$f(x) = 2.654437E+1 * \exp(-5.217403E-2*x)$
$R^2 = 7.438456E-1$

Figure 2. Exponential fit to the data of GE Figure 4 (approximate)

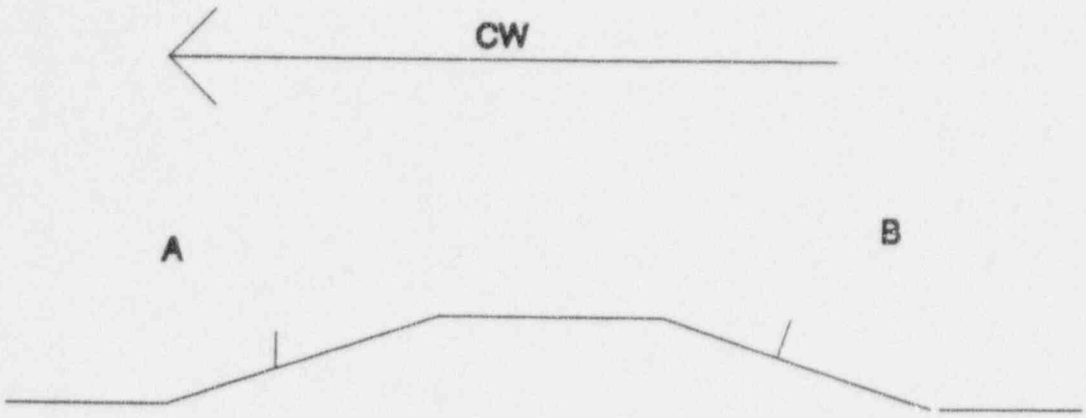


Figure 3. Direction of UT Transducer over Grindout Flaw

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