Commonwealth Edison Company
Byron & Braidwood Stations
Units 1 & 2

Eddy Current
Analysis Guidelines

Rev. 7
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COMMONWEALTH EDISON

1.0 PURPOSE

1.1 The purpose of this guideline is to provide general instructions and to define specific requirements for the analysis of eddy current data acquired from the Commonwealth Edison Company (CECO) Byron and Braidwood Units 1 & 2 steam generators.

1.2 Analysis guidelines provide a structure to ensure that data is (a) analyzed in accordance with the appropriate techniques and practices that reflect current industry experience, (b) in a consistent and repeatable manner and (c) in compliance with CECO requirements.

1.3 Conditions encountered during the course of a steam generator examination not foreseen by this guideline are to be reported by data analysts to the Lead or Senior Analyst .

2.0 SCOPE

2.1 This guideline provides instructions and define specific requirements for bobbin and rotating probe eddy current data analysis for the Byron and Braidwood Station steam generators.

2.2 This guideline also provides direction in applying analysis requirements for an outer diameter stress corrosion cracking at tube support plates Alternate Plugging Criterion (APC).

3.0 RESPONSIBILITIES

3.1 Commonwealth Edison is responsible for interpreting, maintaining and implementing these guidelines, and determining plant specifc APC eddy current data analysis applicability.

3.2 The Senior Analyst, shift Lead Analysts, and data Analysts are selected by CECO or the eddy current vendor with CECO concurrence. Responsibilities of these Analysts are as follows:

3.2.1 <u>Senior Analyst</u>

a. Analyze eddy current data in accordance with this guideline.

b. Identify and process required changes to the guideline during the course of the examination as circumstances may warrant. Changes are documented using the Analysis Guideline Change Form in Appendix B to this guideline and are subject to CECO approval.

c. Promptly inform all data Analysts of changes to this guideline as such changes occur. The Analysis Guideline Change Acknowledgment Form in Appendix B is used to document receipt and review of changes by all Analysts.

d. Perform duties of Lead Analyst or Analyst as required.

3.2.2 <u>Lead Analyst</u>

a. Analyze eddy current data in accordance with this guideline.

b. As a *Resolution Analyst*, resolve discrepancies between primary and secondary Analysts and resolve LAR (Lead Analyst Resolution) calls in accordance with the resolution criteria in Section 9 of this guideline.

c. Promptly inform the Senior Analyst of circumstances that arise during the course of data analysis that are not consistent with or not addressed by this guideline and may require changes.

3.2.3 Analyst

a. Analyze eddy current data in accordance with this guideline.

b. For each calibration group of data analyzed, prepare and submit a final report consistent with this guideline that is complete and free of errors.

c. As a *Resolution Analyst*, resolve discrepancies between primary and secondary Analysts in accordance with the resolution criteria in Section 9.0 of the guideline.

4.0 PERSONNEL QUALIFICATIONS

4.1 Personnel analyzing data shall be qualified in accordance with SNT-TC-1A and certified to Level IIA or Level III.

4.2 In addition, the analyst shall have received training in the evaluation of eddy current data for nonferromagnetic tubing.

4.3 Data analysts will successfully pass a CECO eddy current data Analyst performance demonstration program consisting of site-specific training and testing prior to analyzing production data.

5.0 GENERAL ANALYSIS REQUIREMENTS

5.1 All recorded indications shall be evaluated in accordance with this guideline. Guideline changes must be implemented using the change form given in Appendix B.

5.2 There is no minimum voltage threshold for reporting indications believed to be attributable to tube wall degradation.

5.3 Data analysis consists of reviewing Lissajcus and strip chart displays to the extent that all indications of tube wall degradation and other signals as defined by this document are reported and dispositioned in accordance with the requirements of this document.

5.3.1 All recorded data shall be evaluated regardless of the extent tested.

5.3.2 Phase angle measurements shall be made utilizing VOLTS MAXRATE for signals which have a well-defined transition. For cases where no clear transition exists, a VOLTS PEAK-TO-PEAK approach shall be used. The use of guess angle shall be kept to a minimum and only used when the latter two analysis functions do not give a good representation of the signal phase angle.

5.3.3 Indications for which there are no applicable reporting criteria or which the Analyst considers to be ambiguous or indeterminate should be reported as LAR. The Lead Analyst must resolve such indications with the concurrence of the Senior Analyst.

5.4 All acquired data shall be subject to two independent analyses. These are referred to as "primary" and "secondary" analyses.

5.4.1 The two individual analysis results shall be reviewed for discrepancies in accordance with Section 9.0 of this guideline.

5.4.2 If no discrepancies exist between the primary and secondary analyses, then the primary analysis results shall be considered as final.

5.5 All previous history must be addressed. If no indication is identified at the previous reported location an INF or INR

analysis code (See Appendix C) will be used.

5.6 Axial locations in the hot leg shall be reported in a positive direction from supports, AVB's, tube sheet, and tube end up to but not including 011C.

5.7 Axial locations in the cold leg shall be reported in a positive direction from supports, tube sheet, and tube end up to 011C.

5.8 Probe speed (axial traverse speed and RPM as applicable) should be verified on the following occasions:

5.8.1 At each calibration run.

5.8.2 At any time probe speed is questionable.

5.9 Storing Analysis Setups

5.9.1 The analysis setup established for each calibration group shall be stored to the data recording medium.

5.9.2 Each primary, secondary or resolution Analyst shall store results to primary, secondary, or resolution files respectively.

5.10 Reporting Criteria

5.10.1 The record of each tube analyzed shall include the Tube ID; VOLTS, DEG, % or three letter code, CH# and axial location corresponding to any reported indication(s); and the extent tested.

5.10.2 Acceptable three letter analysis codes for reported indications that are not assigned a percent through-wall are identified in Appendix C of this guideline.

5.10.3 Support structure (landmark) nomenclature and measurements are identified in Appendix D of this guideline.

5.11 Calibration Verification

5.11.1 ASME Standard

a. Calibration verification shall be performed at the beginning and end of each calibration group. If the requirements are not met for bobbin probe data then the data Analyst will identify the affected data and determine which tubes, if any, require retest.

b. The ASME calibrations shall be compared within the following parameters using Channel 1:

(1) The phase angle of the 100% through-wall hole response should be at 40° +/- 5°.

(2) The phase angle of the 20% drill hole response should be between 50° and 130° clockwise from the 100% drill hole response.

(3) Responses from the calibration discontinuities should be clearly indicated and discernible from each other and probe motion.

6.0 BOBBIN PROBE ANALYSIS

6.1 Setup and Calibration

6.1.1 Examination Frequencies

Examination frequencies and channel assignments are given in Table 6-1.

Table 6-1
Tube Examination Frequencies

Frequency (kHz)	Differential Channel	Absolute Channel
550	1	2
300	3	4
130	5	6
10	7	8

6.1.2 Setting Mixes

The mixes in Table 6-2 shall be established.

Table 6-2
Mix Setup

Mix	Channel Sequence	Suppress on:	Save on:
Mix 1	1-5	Support Ring	N/A
Mix 2	4-6	Support Ring	N/A
Mix 3 (Optional)	1-3-5	Support Ring + Clean TTS	ASME Cal Std Drill Holes & OD Groove

Additional mixes may be established for screening and diagnostic applications at the discretion of the analyst. However, as a minimum, data screening and reporting shall be conducted using the applicable channels specified in Section 6.2.

a. Mix 1: 550/130 KHz differential support mix; mix on ASME standard support ring. Set 3-point phase angle-depth calibration curve using ASME 100%, 60%, and 20% drill hole signals. Mix #1 is the primary channel for reporting indications at support structures (other than AVB's).

b. Mix 2: 300/130 KHz absolute; mix on ASME support ring signal. Set amplitude (voltage) 3-point calibration curve (VERTMAX) using the 0%, 20%, and 40% AVB wear scar signals. (Note: 50% wear scar may by substituted if 40% wear scar does not exist in standard). Mix 2 is used for reporting indications at AVB's.

c. Mix 3 (optional): 550/300/130 KHz differential; suppress ASME support plate and normal in-generator roll expansion signal; save signals from ASME standard drill holes. Mix 3 is used to screen TTS expansion regions for indications and to aid in the confirmation of other indications.

6.1.3 Setting Rotations

a. Channels 1,3, and 5: Adjust the rotation so that the phase angle of the signal from the 100% through-wall hole is 40 degrees (+/- 2 degree) with initial signal excursion down and to the right as the probe is pulled through the calibration standard.

b. Channels 2,4, 6, and Mix 2: Adjust the rotation so that probe motion is horizontal with the through-wall hole signal starting upwards.

c. Channel 6: As an option, the signal response from the ASME 100% drill hole may be rotated to 32° (+/- 2°).

d. Channels 7 and 8: Adjust the rotation so that the initial excursion of the signal from the support ring is oriented vertically starting downwards.

e. Mix 1 and Mix 3: Set probe motion horizontal with the signal from the 100% drill

hole starting downwards and to the right (signal will be at about 35 degrees).

6.1.4 Setting Spans

a. Channel 1 and Mix 1: As a minimum, set span so that the magnitude of the ASME 20% drill hole response is approximately 25% of the full screen height (FSH) of the Lissajous display. Verify that the magnitude of the ASME 100% drill hole response is at least 50% of FSH.

b. Mix 2: Set span so that the magnitude of the AVB 20% wear scar response is approximately 25% of FSH.

c. Locator Channels 7 and 8: Set span so that the magnitude of the support plate response on Channels 7 and 8 are at least 50% and 25% of FSH, respectively.

6.1.5 Setting Volts

a. Channel 1: Set the ASME 20% FBH signal to 4 volts +/- 0.1 volts peak-to-peak in Channel 1 and save/store to all other channels and mixes.

b. Mix 1: If an ARC calibration standard is used to establish a voltage scale, then the voltage shall be set to the normalized value on the applicable transfer standard drawing. Save/store to Mix 1. If an ASME calibration standard is used, then set the 20% FBH signal to 2.75 volts +/- 0.1 volts peak-to-peak in Mix 1. Save/store to Mix 1.

c. Mix 2: Set the 40% wear scar signal (or 50% wear scar signal if applicable) to 5 volts (VERTMAX). Save/store to Mix 2.

6.1.6 Calibration Curves

a. Calibration Standard Hole Depths:

(1) The actual depths corresponding to the nominal depths provided below shall be used in establishing calibration curves. "As built" hole dimensions shall be obtained from the applicable calibration standard drawings.

(2) Normalized calibration curves generated using phase angles based on a nominal wall thickness and a standard depth of penetration of 37% are permitted if the requirements of Section 6.1.6.a.1 cannot be satisfied.

b. Use of Artificial Curves: The use of artificial curves e.g., set 4.1, is prohibited.

c. Mix 1 and Channels 1,3, and 5: Establish *phase angle* versus *depth* curves using the following nominal set points:

Set Point 1:	100%
Set Point 2:	60%
Set Point 3:	20%

d. Mix 2: Establish a VERT MAX *voltage* versus *depth* curve using either of the following two cases of typical nominal set points, depending on the AVB calibration standard used:

	Case 1	Case 2
Set Point 1:	0%	0%
Set Point 2:	20%	30%
Set Point 3:	40%	50%

e. Mix 3 (Optional Turbo Mix): No calibration curve is required.

6.1.7 Data Display

a. As a minimum, set up the display configuration for initial data screening according to Table 6-3 using the span settings established in Section 6.1.4.

Table 6-3
Minimum Display Configuration Requirements

Display	Channel
Lissajous	CH 1
Left Strip Chart	CH 6 Vertical
Right Strip Chart	Mix 1 Vertical

6.1.8 Setting Scale and Axial Locations

a. Set the axial scale to the nearest one-hundredth (0.00) of an inch using Appendix C for dimensions and verify proper setting each time an indication is reported.

b. Scale should be set using the two support structures which bound the region of interest. For U-Bend indications, set scale using the two uppermost TSP's on either leg of the steam generator.

(1) Use the TSP centerline as the zero reference point when setting scale between TSP's.

(2) Use the top of the tubesheet and next TSP or baffle plate centerline when setting scale between the top of the tubesheet and the lowest TSP or baffle plate.

(3) Use the tube end and top of tubesheet when the region of interest is within the tubesheet.

c. Axial locations of indications are measured with a positive offset and physically upward in relation to the adjacent landmark.

(1) Locations of indications within the boundaries of support and baffle plates are referenced (+) or (-) as they occur above or below the support structure centerline.

(2) Indications within the expansion transition region near the secondary tubesheet face are referenced relative to the top of the tubesheet.

(3) U-bend indications are referenced (+) in relation to the adjacent AVB toward the hot-leg or upper hot-leg support plate as appropriate.

(4) AVB indications are referenced to (0.00) at the corresponding AVB.

d. Location landmarks are identified using the appropriate three-letter codes as specified in Appendix C.

6.2 DATA EVALUATION

6.2.1 This section defines special augmented data screening and analysis requirements for various classes of indications. Particular attention should focus on analysis procedures for 1) free-span indications, and dings. Both of these types of indications have been associated with recent industry forced outages in preheater steam generators.

In addition, evaluation requirements for screening support structures, e.g., support and baffle plates, AVB's, and the tubesheet secondary face, are described.

a. Free-Span Sections (Byron 1 and Braidwood 1 Only):

- **Ding Signal Screening**

1. Free-span ding signals discovered during data screening shall be scrolled in the Lissajous window using Channels 1, 3 and 5.

2. Distorted indications observed during data review shall be reported as *FSI* for subsequent disposition by rotating probe diagnostics.

3. It should be noted that generally distorted indications are more apparent in Channels 3 and 5, and often are not evident in Channel 1 because of the overwhelming horizontal response caused by local tube indentation or deformation.

- **U-bend region**

<u>*Data Screening (Data Analysts)*</u>

1. The U-bend region *between the uppermost support plates* shall be scrolled in the Lissajous window using *Channel 5* at a numerical span setting of *10 or less.*

2. Possible indications observed in Channel 5 should be confirmed using Channel 3. It is emphasized that definitive indications *may not always be observed in either of the two channels*. Rather, the indications may assume a noise-like structure, with multiple discrete indications occurring in close proximity over a longer axial distance.

3. Report all confirmed indications using an *Free-Span Signal* (FSS) analysis code. Subsequent disposition of all reported indications will be accomplished by a resolution analyst.

4. Single indications may be reported using a discrete location while multiple indications in close proximity may be reported using a to-from location.

5. Figure 6-1 shows a flowchart illustrating U-bend data screening and reporting requirements.

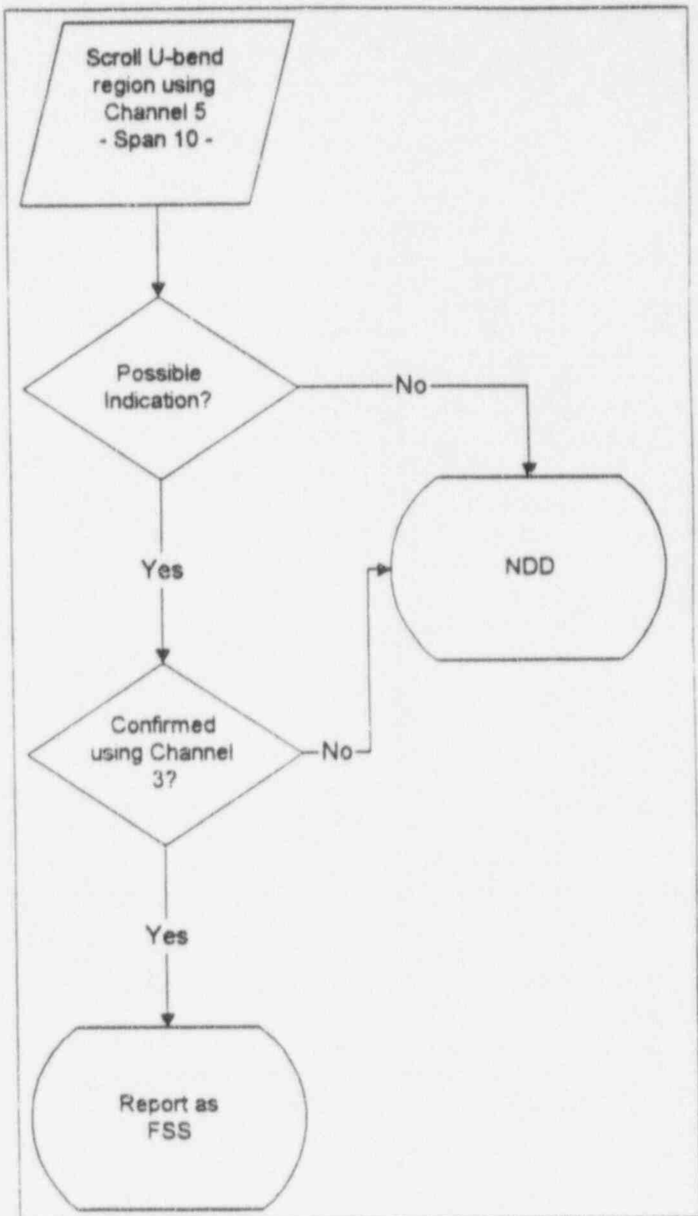

Figure 6-1.
Data screening requirements for U-bend free-span indications.

Disposition (Resolution Analysts)

1. Previous history or rotating probe diagnostics shall be used to disposition U-bend free-span signals.

2. U-bend free-span signals may be further reclassified as *Free-Span Differential* (FSD), *Manufacturing Burnish Mark* (MBM) etc., depending on the relative response of the absolute/differential bobbin coil modes.

3. U-bend free-span signals identified for repair shall be reclassified as a *Free-Span Indication* (FSI).

b. Support Plates and Baffle Plates:

Conventional Plugging Criterion:

1. Scroll support plates using Channels 3 and Mix 1. *There is no minimum threshold voltage for reporting.*

2. Channel 3 is usually a very useful channel for data screening and locating the initial position for *phase angle* measurement.

3. Mix 1 shall be used to determine the final *phase angle* measurement point.

Alternate Plugging Criterion:

1. Scroll support plates using Channels 3 and Mix 1. *There is no minimum threshold voltage for reporting* purposes.

2. Initial placement of the dots for identification of the flaw location may be performed using Channels 1 or 3, but the final peak-to-peak measurements must be performed using the Mix 1 Lissajous signal to include the *full flaw segment* of the signal. It may be necessary to iterate the positions of the measurement points between the identifying frequency and the Mix 1 channel to obtain proper placement.

3. The *largest amplitude* portion of the Lissajous signal (not necessarily the MAXRATE position) representing the indication should then be reported using Mix 1 to establish the *voltage*.

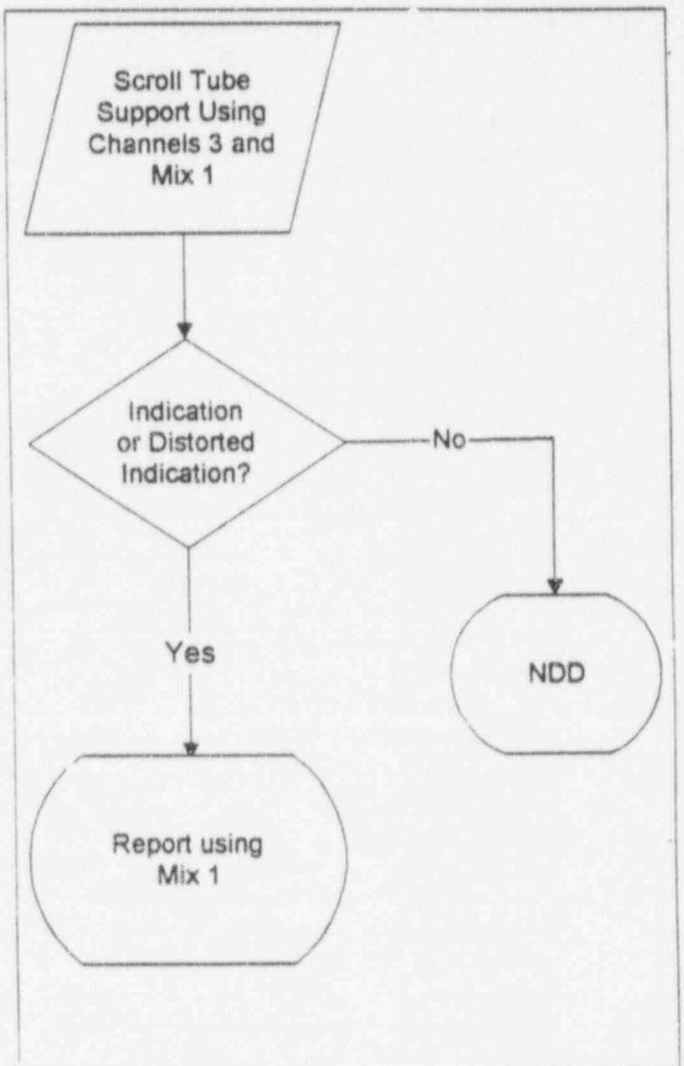

Figure 6-2
Flowchart showing data screening for indications at tube support plates.

c. Antivibration Bars:

1. Scroll antivibration bars locations using Mix 1 or Mix 2.

2. Report indications using the Mix 2 VERTMAX analysis function. Signal amplitude, as measured on the conservative leg of the indication, shall be utilized for sizing indications at AVB's.

3. Figure 6-3 shows a flowchart illustrating data screening and reporting requirements.

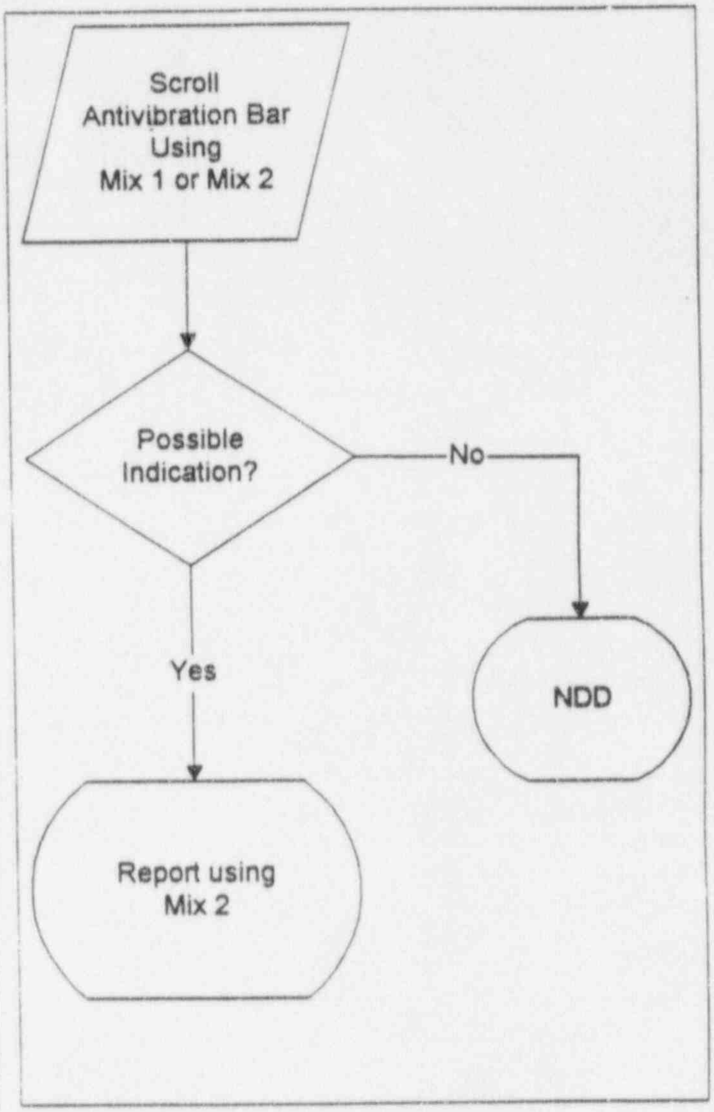

Figure 6-3
Flowchart showing data screening for indications at AVB's.

d. Tubesheet Secondary Face:

1. *Scroll all tubesheet secondary face expansion transitions* using Channels 1, 3, 5, and Mix 1 at span settings such that the expansion signal (except for Mix 1) occupies the maximum extent of the Lissajous display without saturating.

2. As an option, Mix 3 (Turbo mix) may be used to carefully screen for degradation-like indications at the top of the tubesheet.

3. Distorted tube sheet entry signals or possible indications should be reported using the appropriate analysis code.

4. Figure 6-4 shows a flowchart illustrating data screening and reporting requirements.

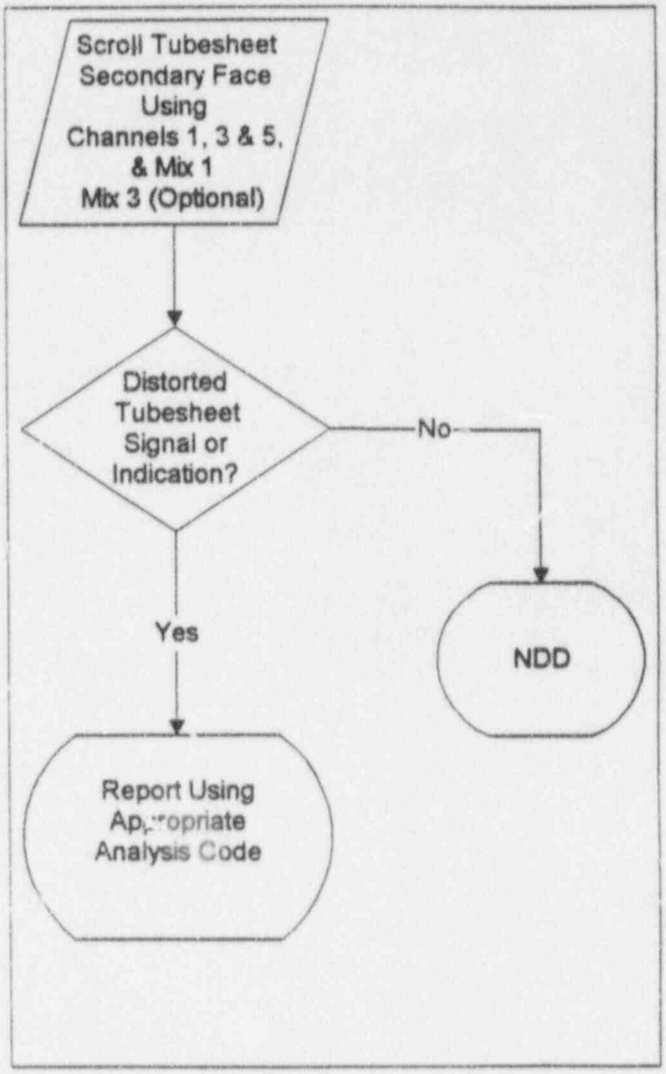

Figure 6-4
Flowchart showing data screening for indications at tubesheet secondary face.

7.0 ROTATING PROBE ANALYSIS

7.1 Setup and Calibration

7.1.1 Examination Frequencies

a. Examination frequencies and channel assignments for a three-coil rotating probe are given in Table 7-1.

Table 7-1
Three-Coil Rotating Probe

Channel	Frequency (kHz)	Coil	Coil Type	Function
1	300	1	Pancake	General Detection
2	300	5	Circ Wound	Axial Detection
3	300	7	Axial Wound	Circumferential Detection
4	200	1	Pancake	General Confirmation
5	200	5	Circ Wound	Axial Confirmation
6	200	7	Axial Wound	Circumferential Confirmation
7	100	1	Pancake	General Confirmation
8	100	4	Pancake	Trigger
9	100	5	Circ Wound	Axial Confirmation
10	100	7	Axial Wound	Circumferential Confirmation
11	10	1	Pancake	Locator

7.1.2 Setting Mixes (Optional)

a. At the option of the data analysts or at the direction of the Lead Analyst, mixes may be established for information only.

7.1.3 Filters (Optional)

a. At the option of the data analysts or at the direction of the Lead Analyst, bandpass filters on process channels P1, P2 and P3 using Channels 1,2 and 3 (300 KHz), respectively, may be established using the nominal settings of Table 7-2. Settings may be adjusted slightly to improve signal-to-noise.

Table 7-2
Bandpass Filter Setup

Parameter	Value
Sharpness	23 coefficients
Low cutoff frequency	10 Hz
High cutoff frequency	100 Hz

7.1.4 Setting Volts

Pancake Coil

a. Set the voltage for Channel 1 to 20.00 +/- 0.3 volts on the largest peak-to-peak response of the 100% EDM notch..

b. Normalize the voltage for other pancake coil channels (CH4 and CH7) in reference to Channel 1. Store to all other channels for that coil.

Circumferential Wound Coil

a. Set the voltage for Channel 2 to 20.00 +/- 0.3 volts on the largest peak-to-peak response of the 100% EDM notch.

b. Normalize the voltage for all other pancake coil channels (CH5 and CH 9) in reference to Channel 2. Store to all other channels for that coil.

Axial Wound Coil

a. Set the voltage for Channel 3 to 20.00 +/- 0.3 volts on the largest peak-to-peak response of the 100% EDM notch.

b. Normalize the voltage for all other pancake coil channels (CH6 and CH10) in reference to Channel 3. Store to all other channels for that coil.

7.1.5 Setting Spans

a. Channels 1,2,4,5,8 & 9: Set spans such that the peak-to-peak response of the axially oriented 40% EDM notch is at least 25% FSH.

b. Channels 3,6 & 10: Set spans to same nominal numerical values as Channels 2,5, and 9 respectively.

c. Channel 8: Set span so that the trigger pulse occupies approximately 50% FSH.

d. Channel 11: Set span so that the support plate occupies 25%-50% FSH.

7.1.6 Setting Rotations

a. Detection/Confirmation Channels: Set probe motion to within +/- 5° of horizontal with flaw excursions directed upwards.

b. Channel 8: Set the trigger pulse vertically upwards at 90°-120°.

c. Channel 11: Set the response of the support plate vertically downward at approximately 270°.

7.1.7 Setting Curves

a. Depth calibration curves are not required. Phase angle or amplitude curves may be established at the Analysts' option for information only.

7.1.8 Setting Scale and Axial Locations

a. Using Channel 1, set scale between the centerlines of two known reference locations of greatest separation on the EDM notch standard.

b. Verify proper scale setting when reporting each indication.

c. For support plate indications, axial locations should be referenced positively (+) upward or negatively (-) downward from the centerline (0.00) of the nearest support plate.

d. For top of tubesheet indications, axial locations should be referenced positively (+) upward or negatively downward from the top of the tubesheet zero (0.00) reference.

7.1.9 Display Configuration

a. Setup the display configuration for initial data screening according to Table 7-3 using span settings established above.

7.1.10 C-Scan

a. C-scan features shall be adjusted consistent with the software suppliers recommended practice.

Table 7-3
Display Configuration

Display	Channel
Lissajous	CH 1 (300 kHz)
Left Chart	CH 1 or CH P1 Vertical
Right Chart	CH 2 or CH 3 Vertical

7.1.11 Indication Length Measurements

a. Indication length measurements are required.

b. Software features for measuring indication lengths will be invoked consistent with the software supplier's recommended practice.

c. Setup of measurement features should be done using the nominal tube ID and the as-built dimensions of the EDM notch standard discontinuities.

7.2 Data Evaluation

7.2.1 Screening

a. Review strip chart data while scrolling all acquired data using Channel 1 to establish the presence of an indication. Other analysis channels may be used for additional confirmation.

b. Decrease initial span settings (higher gain) as required such that proper detailed analysis is conducted on all data.

c. Indications which are flaw-like on any of the degradation channels shall be reported irrespective of the extent to which the channels correlate.

7.2.2 Analysis

a. Graphic displays and relative three-coil amplitude response shall be used to determine flaw orientation and dimensionality using the basic logic summarized in Figure 7- 1.

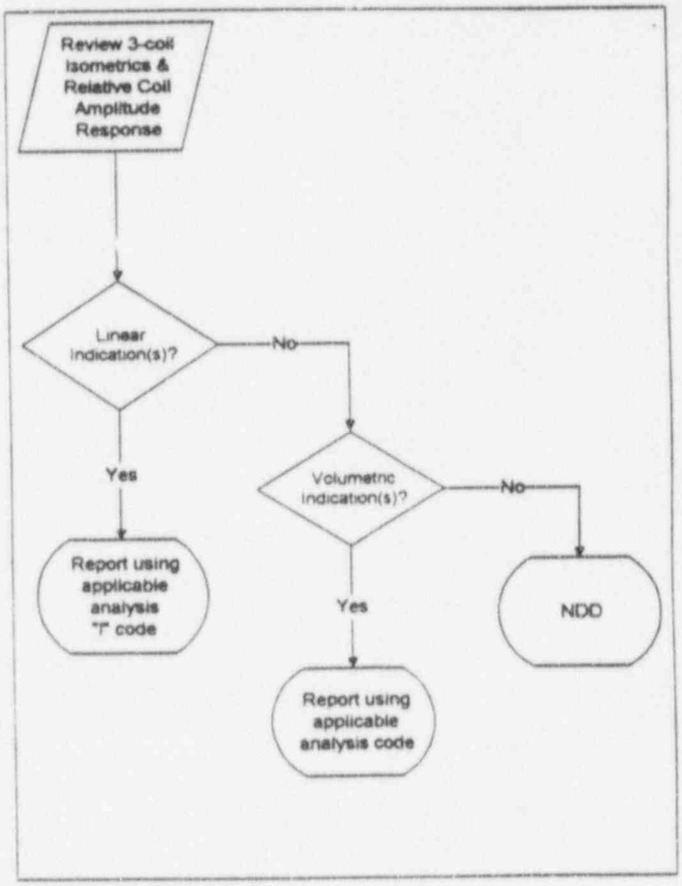

Figure 7-1.
Rotating Probe Analysis

b. Three-coil relative signal response as shown in Table 7-4 may be used to assist in determining flaw dimensionality and orientation.

Table 7-4
Three-coil Relative Amplitude Response

Coil	Flaw Dimensionality/Orientation		
	Vol	**Axial**	**Circ**
Pancake	+	+	+
Axial	+	+	-
Circ	+	-	+

Three-dimensional discontinuities in general will have a comparable response from the pancake and axial/circ coils. Linear or two-dimensional discontinuities will typically show a preferred response to either the axial or circ coils (or both) dependent on flaw orientation. The pancake coil is equally sensitive to linear discontinuities independent of their orientation.

c. Indications with a preferred amplitude response from either the axial or circ coil shall be analyzed using a three-letter analysis code indicative of the orientation (axial or circumferential) and frequency of occurrence in a given plane. Indications with comparable amplitude responses from all three coils shall be analyzed as three-dimensional (volumetric) using an appropriate analysis code. Section 8.2 defines the applicable analysis codes.

e. Locations with both axial and circumferential indications present concurrently shall be analyzed as mixed-mode.

8.0 REPORTING AND RECORDING REQUIREMENTS

8.1 Bobbin Probe

8.1.1 Reporting Requirements

a. All quantifiable indications of tube wall degradation shall be reported. For AVB indications, the reporting threshold is 15%.

b. All non-quantifiable indications (See Appendix B, Category II) shall be reported. As a general rule, Category II indications shall be considered a repairable condition unless proven otherwise using supplemental diagnostic techniques, e.g. RPC or equivalent, or historical review.

c. Dents or dings > 5 volts peak-to-peak (Mix 1).

d. Distorted dents or dings having flaw-like characteristics shall be reported as LAR.

e. Actual test extent shall be reported as the furthest landmark from the entry leg observed.

8.1.2 Recording Requirements

a. As a minimum, the following graphic printouts shall be generated for each reported quantifiable indication, "I" code indication, Free-Span Signal (FSS) and LAR indication:

1. Multiple-channel Lissajous graphics as specified in Tables 8-1 or Table 8-2.

b. The following information will be recorded in the FINAL REPORT section of the RECORDING MEDIUM:

1. For each tube evaluated, an entry must be made that, as a minimum, contains the S/G, ROW, COL, and EXTENT tested.

2. The evaluation of all indications to include the S/G, ROW, COL, VOLTS, DEG, %, CH#, LOCATION, and EXTENT tested.

3. Any RESTRICTED tubes and the location where probe passage is obstructed. Restricted locations must include elevation where restriction occurs.

c. The SUMMARY portion of the RECORDING MEDIUM shall include:

1. All information recorded on the RECORDING MEDIUM and updated to reflect the actual spans and rotations used during data evaluation.

2. The NAME(S) and LEVEL(S) of the evaluator(s) along with the date of the evaluation.

Table 8-1
Eight-Channel Graphics

Location	Lissajous	Charts
Supports	1,3,5, Mix 1 2,4,6, Mix 2	Mix 1
AVB's	1,3,5, Mix 1, 2,4,6, Mix 2	Mix 2
Free Span	1,3,5, Mix 1 2,4,6, Mix 2	5
TTS	1,3,5, Mix 1 2,4,6, Mix 2 or Mix 3	Mix 1

Table 8-2
Four-Channel Graphics

Location	Lissajous	Charts
Supports	1,3,5, Mix 1	6, Mix 1
AVB's	1,3,6, Mix 2	6, Mix 2
Free Span	1,3,5,6	1, 5
TTS	1,3,5, Mix 1	5, Mix 1

8.2 Rotating Probe

8.2.1 Reporting Requirements

a. The voltage of an indication will be measured at the peak signal for each indication. This will generally be at the centermost "hit" of the indication using the detection channel (CH 1 typically). Peak-to-peak voltage should be used for the voltage reading, adjusting the window width to minimize noise in the signal.

b. Indication location will be derived from the centermost "hit" point of the calling channel.

c. Indications will not be reported as a percent depth, but assigned an analysis code indicative of the dimensionality, orientation and frequency of occurrence of the flaw in a given plane. Permissible analysis codes are listed in Appendix D.

8.2.2 Recording Requirements

The following graphic printouts should be generated for each reported indication:

a. Main display screen typically with the Lissajous of the calling channel (CH 1), left strip chart of a low frequency channel adequate to display the bounding or nearest support and right strip chart with the vertical component of a confirmatory channel (e.g., CH P1 or CH 2).

b. C-scan of indication with the low frequency channel displayed on the strip chart and either the calling channel or corresponding filtered channel for the C-scan plot.

9.0 RESOLUTION CRITERIA

9.1 Primary and secondary analyses results will be compared and referred to the Senior

and/or Lead analysts for resolution and disposition.

9.2 Conditions requiring resolution include:

9.2.1 All quantifiable indications $\geq$ 40% through-wall, and Category 2 Indications listed in Appendix C where primary and secondary analysis results do not match.

9.2.2 Quantifiable indications between 20% and 39% reported by one Analyst but not the other.

9.2.3 Indications in which the depth estimate differs by more than 10% through-wall

9.2.4 Indications for which location measurements differ by more than;

a. +/- 1" for free-span.

b. +/- 0.5" at support structures.

9.2.5 Indications at tube support plates f*or plants implementing APC* for which;

a. Bobbin coil indications are greater than the repair limit voltage where primary and secondary analysis results do not match.

b. The reported location extends beyond either support plate edge.

c. Indications are diagnosed as circumferential cracking. by RPC.

d. The bobbin coil voltage values called by primary and secondary analysts deviate by more than 20% and o*ne or both calls* exceeds 1 volt.

9.2.6 Reporting errors or discrepancies in such items as steam generator, tube or reel ID, probe type, extent tested, analysis code assignment, etc.

9.2.7 One analyst reports a tube not reported by another.

9.3 *Any tube* with an initially reported repairable condition - by either the primary or secondary analyst, or both - *that is subsequently resolved to a non-repairable condition during resolution* - shall be reported to a CECO representative for information.

APPENDIX A

NDE DATA ACQUISITION AND ANALYSIS GUIDELINES FOR ODSCC AT TSP APC

A.1 INTRODUCTION

This appendix documents techniques for the inspection of Byron and Braidwood Unit 1 steam generator tubes related to the identification of ODSCC or IGA/SCC at tube support plate (TSP) regions.

This appendix contains guidelines which provide direction in applying the ODSCC alternate plugging criteria (APC) described in this report. The procedures for eddy current testing using bobbin coil (BC) and rotating pancake coil (RPC) techniques are summarized. The procedures given apply to the bobbin coil inspection, except as explicitly noted for RPC inspection. The methods and techniques detailed in this appendix are requisite for implementation of TSP APC.

The following sections define specific acquisition and analysis parameters and methods to be used for the inspection of steam generator tubing.

A.2 DATA ACQUISITION

Byron and Braidwood Unit 1 steam generators utilize 3/4" OD x 0.043" wall, Alloy 600 milll-annealed tubing. The carbon steel support plates and baffle plates are designed with drilled holes. The following guidelines are specified for non-destructive examination of the tubes within the TSP at Byron Unit 1.

A.2.1 Instrumentation

Eddy current equipment used shall be the Zetec MIZ-18, the Echoram ERDAU or other equipment with similar specifications.

A.2.2 Probes

A.2.2.1 Bobbin Coil Probes

To maximize consistency with laboratory APC data, differential probes with the following parameters shall be used for examination of APC tube support plate intersections:

- 0.610 outer diameter

- two bobbin coils, each 60 mils long, with 60 mils between coils (coil centers separated by 120 mils)

In addition, the probe design must incorporate centering features that provide for minimum probe wobble and offset; the centering features must maintain constant probe center to tube ID offset for nominal diameter tubing. For locations which must be inspected with smaller than nominal diameter probes, it is essential that the reduced diameter probe be calibrated to the reference normalization (Section A.2.6.1 and A.2.6.2) and that the centering features permit constant probe center to tube ID offset.

A.2.2.2 Rotating Pancake Coil Probes

Pancake coil designs (vertical dipole moment) with a coil diameter d, where d is 0.060" $\leq$ d $\leq$ 0.125", shall be used. While other multi-coil (i.e., 1,2 or 3-coil) probes can be utilized, it is recommended that if a 3-coil probe is used, any voltage measurements should be made with the probe's pancake coil rather than its circumferential or axial coil.

The maximum probe pulling speed shall be 0.2 in./sec for the 1-coil or 3-coil probe, or 0.4 in/sec. for the 2-coil probe. The maximum rotation shall be 300 rpm. This would result in a pitch of 40 mils for the 3-coil probe.

A.2.3 Calibration Standards

A.2.3.1 Bobbin Coil Standards

The bobbin coil calibration standards contain the following items:

• Voltage Normalization Standard

- One 0.052" diameter 100% through wall hole

- Four 0.028" diameter through wall holes, 90 degrees apart in a single plane around the tube circumference; the hole diameter tolerance shall be +/- 0.001" (optional).

- One 0.109" diameter flat bottom hole, 60% through from OD

- One 0.187" diameter flat bottom hole, 40% through from the OD

- Four 0.187" diameter flat bottom holes, 20% through from the OD, spaced 90 apart in a single plane around the tube circumference. The tolerance on hole diameter and depth shall be +/-0.001".

- A simulated support ring, 0.75" long, comprised of SA-285 Grade C carbon steel or equivalent.

All holes shall be machined using a mechanical drilling technique. This calibration standard will need to be calibrated against the reference standard used for the APC laboratory work by direct testing or through the use of a transfer standard.

• Probe Wear Standard

- A probe wear standard for monitoring the degradation of probe centering devices leading to off-center coil positioning and potential variations in flaw amplitude responses. This standard shall include four 0.052" +/- 0.001 inch diameter through-wall holes, spaced 90 degrees apart around the tube circumference with an axial spacing such that signals can be clearly distinguished from one another. See Figure A-1.

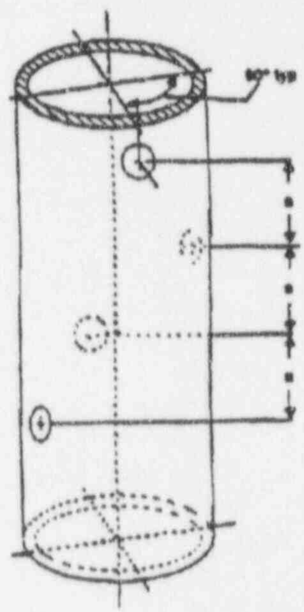

Figure A-1. Probe Wear Standard Schematic

A.2.3.2 Rotating Probe Standard

A satisfactory RPC standard may contain:

- Two axial EDM notches, located at the same axial position but 180 degrees apart circumferential, each 0.006" wide and 0.5" long, one 80% and one 100% through wall from the OD.

- Two axial EDM notches, located at the same axial position but 180 degrees apart circumferentially, each 0.006" wide and 0.5" long, one 60% and one 40% through-wall from the OD.

- Two circumferential EDM notches, one 50% through wall from the OD with a 75 degree (0.57") arc length, and one 100% through wall with a 26 degree (0.20") arc length, with both notches 0.006" wide.

- A simulated support segment 270 degrees in circumferential extent, 0.75" thick, comprised of SA-285 Grade C carbon steel or equivalent.

Similar configurations which satisfy the intent of calibrating RPC probes for OD axial and circumferential cracking are satisfactory. The center to center distance between the support plate simulation and the nearest slot shall be at least 1.25". The center to center distance between the EDM notches shall be at least 1.0". The tolerance for the widths and depths of the notches shall be 0.001". The tolerance for the slot lengths shall be 0.010".

A.2.4 Application of Bobbin Coil Wear Standard

A calibration standard has been designed to monitor bobbin coil probe wear. During steam generator examination, the bobbin probe is inserted into the wear monitoring standard; the initial (new probe) amplitude response from each of the four holes is determined and compared on an individual basis with subsequent measurements. Signal amplitudes or voltages from the individual holes - compared with their initial amplitudes - must remain within 15% of their initial amplitude (i.e., {(worn-new)/new} for an acceptable probe wear condition. If this condition is not satisfied, then the probe must be replaced. If any of the last probe wear standard signal amplitudes prior to probe replacement exceeds the 15% limit, say by a variable value, x%, then indications measured since the last acceptable probe wear measurement that are within x% of the repair limit must be re-inspected with the new probe.

A.2.4.1 Bobbin Coil Wear Standard Placement

Under ideal circumstances, the incorporation of a wear standard in line with the conduit and guide tube configuration would provide continuous monitoring of the behavior of bobbin probe wear. However, the curvature of the channelhead places restrictions on the length on in line tubing inserts which can be accommodated. The spacing of the ASME Section XI holes and the wear standard results in a length of tubing which cannot be freely positioned within the restricted space available. The flexible conduit sections inside the channelhead, together with the guide tube, limit the space available for additional in line components. Voltage responses for the wear standard are sensitive to bending of the leads, and mock up tests have shown sensitivity to the robot end effector position in the tubesheet, even when the wear standard is placed on the bottom of the channelhead. Wear standard measurements must permit some optimization of positions for the measurement and this should be a periodic measurement for inspection efficiency. The pre-existing requirement to check calibration using the ASME tubing standard is satisfied by periodic probing at the beginning and end of each probe's use as well as at four hour intervals. This frequency is adequate for wear standard purposes as well. Evaluating the probe wear under uncontrollable circumstances would present variability in response due to channelhead orientations rather than changes in the probe itself.

A.2.5 Acquisition Parameters

The following parameters apply to bobbin coil data acquisition and should be incorporated in the applicable inspection procedures to supplement (not necessarily replace) the parameters normally used.

A.2.5.1 Test Frequencies

This technique requires the use of bobbin coil 550 kHz and 130 kHz test frequencies in the differential mode. It is recommended that the absolute mode also be used, at test frequencies of 130 kHz and 10 - 35 kHz. The low frequency (10-35 kHz) channel should be recorded to provide a means of verifying tube support plate edge detection for flaw location purposes. The 550/130 kHz mix or the 550 kHz differential channel is used to access changes in signal amplitude for the probe wear standard as well as for flaw detection.

RPC frequencies should include channels adequate for detection of OD degradation in the range of 100 kHz to 550 kHz, as well as a low frequency channel to support location of the TSP edges.

A.2.5.2 Digitizing Rate

A minimum digitizing rate of 30 samples per inch should be used. Combinations of probe speeds and instrument sample rates should be chosen such that:

$$\frac{\text{Sample Rate (samples/sec.)}}{\text{Probe Speed (in/sec)}} \geq 30 \text{ (samples/in.)}$$

A.2.6 Analysis Parameters

This section discusses 1) the methodology for establishing bobbin coil data analysis variables such as spans, rotations, mixes, voltage scales, and calibration curves. Although indicated depth measurement may not be required to support an alternative repair limit the methodology for establishing the calibration curves is presented. The use of these curves is recommended for consistency in reporting and to provide compatibility of results with subsequent inspections of the same steam generator and for comparison with other steam generators and/or plants.

A.2.6.1 Bobbin Coil 550 kHz Differential Channel

Spans and Rotations: Spans and rotations can be set at the discretion of the user and/or in accordance with applicable procedures.

Voltage Scale: The peak-to-peak signal amplitude of the signal from the four 20% through-wall holes should be set to produce a voltage equivalent to that obtained from the APC lab standard. The laboratory standard normalization voltages are 4.0 volts at 550 kHz and 2.75 volts for the 550/130 kHz mix.

The transfer/field standard will be calibrated against the laboratory standard using a reference laboratory probe to establish voltages for the field standard that are equivalent to the above laboratory standard. These equivalent voltages are then set on the field standard to establish calibration voltages for any other standard.

Voltage normalization to the standard calibration voltages at 550 kHz is the preferred normalization to minimize analyst sensitivity in establishing the mix. However, if the bobbin probes used result in a 550/130 kHz mix to 550 kHz voltage ratios differing from the laboratory standard ratio of 0.69 by more than 5% (0.66 to 0.72), the 550/130 kHz mix calibration voltage should be used for voltage normalization.

Calibration Curve: Establish a phase versus depth calibration curve using measured signal phase angles in combination with the "as-built" flaw depths for the 100%, 60%, and 20% holes.

A.2.6.2 Bobbin Coil 550/130 kHz Differential Mix Channel

Spans and Rotations: Spans and rotations can be set at the discretion of the user and/or in accordance with applicable procedures.

Voltage scale: See Section A.2.6.1

Calibration Curve: Mix 1 is a 550/130 kHz differential support mix; mix on ASME standard support ring. Set 3-point phase angle-depth calibration curve using ASME 100%, 60%, and 20% drill hole signals. Mix 1 is the primary channel for reporting indications at support structures.

A.2.6.2 Rotating Pancake Coil Channel

Voltage Scale: The RPC amplitude will be referenced to 20 volts for a 0.5 inch long 100% through wall notch at 300 kHz. Each channel shall be set individually to the desired amplitude for the EDM notches on the plant standards; cross calibration will be achieved by comparison of the RPC responses from the 100% drilled hole.

A.2.7 Analysis Methodology

Bobbin coil indications at support plates attributable to ODSCC are quantified using the Mix 1 (550 kHz/130 kHz) data channel. This is illustrated with the example shown in Figure A-2. The 500/130 kHz mix channel or other channels appropriate for flaw detection (550 kHz, 300 kHz, or 130 kHz) may be used to locate the indications of interest within the support plate signal. The largest amplitude portion of the Lissajous signal representing the flaw should then be measured using the 550/130 kHz Mix 1 channel to establish the peak-to-peak voltage as shown in Figure A-2. Initial placement of the dots for identification of the flaw location may be performed as shown in Figures A-3 and A-4, but the final peak-to-peak measurements must be performed on the Mix 1 Lissajous signal to include the full flaw segment of the signal. It may be necessary to iterate the positions of the dots between the identifying frequency and the 550/130 kHz mix to obtain proper placement. As can be seen in Figure A-4, failure to do so can reduce the voltage measurement of Mix 1 by as much as 65% to 70% due to the interference of the support plate signal in the raw frequencies. The voltage as measured from Mix 1 is then entered as the analysis of record for comparison with the repair limit voltage.

To support the uncertainty allowances maintained in the APC, the difference in amplitude measurements for each indication will be limited to 20%. If the voltage values called by the independent analysts deviate by more than 20% and one or both of the calls exceeds 1.0 volts, analysis by the resolution analyst will be performed. These triplicate analyses result in assurance that the voltage reported departs from the correct call by no more than 20%.

A.2.8 Reporting Guidelines

The reporting requirements identified below, are in addition to any other reporting requirements specified by the user.

A.2.8.1 Minimum Requirements

All bobbin coil flaw indications in the 550/130 kHz mix channel at the tube support plate

intersections regardless of the peak-to-peak signal amplitude must be reported. All TSP locations with indications exceeding 1.0 volts must be examined with RPC probes.

A.2.8.2 Additional Requirements

For each reported indication, the following information should also be recorded:

Tube identification (row, column)
Signal amplitude (volts)
Signal phase angle (degrees)
Indicated depth (%)*
Test Channel (ch#)
Axial position of tube (location)
Extent of test (extent)

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* It is recommended that a percent through-wall be reported rather than a three-letter analysis code. While this measurement is not required, this information might be found useful at a later date.

RPC reporting requirements should include as a minimum: type of degradation (axial, circumferential or other), maximum voltage, phase angle, crack lengths, and location of the center of the crack within the TSP. The crack axial center to edge need not coincide with the position of maximum amplitude. Locations which do not exhibit flaw-like indications in the RPC isometric plots may continue in service, except that all intersections exhibiting flaw-like bobbin behavior and bobbin amplitudes in excess of the repair limit voltage must be repaired, notwithstanding the RPC analyses. RPC isometrics should be interpreted by the analyst to characterize the signals observed; only featureless isometrics are to be reported as NDD. Signals not interpreted as flaws include dents, liftoff, deposits, copper, magnetite, etc.

A.3 DATA EVALUATION

A.3.1 Use of 550/130 Differential Mix for Extracting the Bobbin Flaw Signal

In order to identify a discontinuity in the composite signal as an indication of a flaw in the tube wall, a simple signal processing procedure of mixing the data from the two test frequencies is used which reduces the interference from the support plate signal by approximately one order of magnitude. The test frequencies most often used for this signal processing are 550 kHz and 130 kHz for 43 mil wall Alloy 600 tubing. Any of the differential data channels including the mix channel may be used for flaw detection (though the 130 kHz is often subject to the influence from many different effects), but the final evaluation of signal detection, amplitude and phase angle will be made from the 550/130 kHz differential mix channel. Upon detection of a flaw signal in the differential mix channel, confirmation from other raw channels in not required; all such signals must be reported as indications of possible ODSCC. The voltage scale for the 550/130 kHz differential channel should be normalized as described in Section A.2.2.6.1 and A.2.2.6.2.

The present evaluation procedure requires that there is no minimum voltage for flaw detection purposes and that all flaw signals, however small, be identified. The intersections with flaw signals ≥ 1.0 volt will be inspected with RPC, unless the tube is to be plugged or sleeved. Although the signal voltage is not a measure of flaw depth, it is an indicator of the tube burst pressure when the flaw is identified as axial ODSCC with or without minor IGA.

A.3.2 Amplitude Variability

It has been observed that voltage measurements taken from the same data by

different analysts may vary, even when using identical analysis guidelines. This is largely due to differences in analyst interpretation of where to place the dots on the lissajous figure for the peak-to-peak amplitude measurement. Figures A-5 and A-6 show the correct placement of the dots on the Mix 1 Lissajous figures for the peak-to-peak voltage amplitude measurements for two tubes from Plant S. In Figure A-5, the placement is quite obvious. In Figure A-6, the placement requires slightly more of a judgment call. Figures A-7 and A-8 show these same two tubes with peak-to-peak measurements being made, but in both cases the dots have been placed at locations where the normal max-rate dots would be located. The reduction in the voltage amplitude measurement is 19.3% in Figure A-7 and 16.3% in Figure A-8. While this is an accepted method of analysis for phase-angle measurements, it is not appropriate for the voltage amplitude measurements required.

In Figures A-5 and A-6, the locations of the dots for the peak-to-peak measurements being performed from Mix 1 show the corresponding dots on the 550 kHz raw frequencies as also being located at the peak or maximum points of the flaw portion of the Lissajous figure. In no case should the should the dots to measure the voltage amplitude be at locations less that the maximum points of the flaw portion of the 550 kHz raw frequency.

Figure A-9 is an example of where the dots have been placed on the transition region of the 550 kHz raw frequency data Lissajous figure. It is clear from the Mix 1 Lissajous figure that this does not correspond to the maximum voltage measurement. The correct placement on the Mix 1 Lissajous figure us shown in Figure A-10. This placement also corresponds to the maximum voltage measurement on the 550 kHz raw frequency data channel.

In some cases, it will be found that little if any definitive help is available from the use of the raw frequencies. Such as example is shown in Figure A-11, where there are no significantly sharp transitions in any of the raw frequencies. Consequently, the placement of the measurement dots must be made completely on the basis of the Mix 1 channel Lissajous figure as shown in the upper left of the graphic. An even more difficult example is shown in Figure A-12. The logic behind the placement of the dots in Mix 1 is that sharp transitions in the residual support plate signals can be observed at the locations of both dots. In the following graphic, Figure A-13, somewhat the same logic could be applied in determining the flaw-like portion of the signal from the Mix 1 Lissajous pattern. However, inasmuch as there is no sharp, clearly defined transition, coupled with the fact that the entry lobe into the support plate is distorted on all of the raw frequencies, the dots should be placed as shown in Figure A-14. This is a conservative approach and should be taken whenever a degree of doubt as to the dot placement exists.

It is noted that by employing these techniques, identification of flaws is improved and that conservative amplitude measurements are promoted. The Mix 1 traces which result from this approach confirm to the model of TSP ODSCC which represents the degradation as a series of microcrack segments axially integrated by the bobbin coil; i.e., short segments of changing phase angle direction represent changes in average depth with changing axial position. This procedure may not yield the maximum bobbin depth call. If maximum depth is desired for information purposes, shorted segments of the overall crack may have to be evaluated to obtain the maximum depth estimate. However, the peak to peak voltages as described herein must be reported, even if a different segment is used for the depth call.

A.3.3 Alloy Property Changes

This signal manifests itself as part of the support plate "mix residual" in both the differential and absolute mix channels. It has often been confused with copper deposit as the cause. Such signals are often found as support plate intersections of operating plants, as well as in some model boiler test samples, and are not necessarily indicative of tube wall degradation. Six support plate intersections from Plant A, judged as free of tube wall degradation on the basis of the mixed differential channel using the guidelines given in Section A.2.7 of this document, were pulled in 1989. Examples of the bobbin coil field data are shown in Figure A-15. (inspection data from a plant with 7/8 inch diameter tubing. The mix residual for this example is approximately 3 volts in the differential mix channel and no discontinuity suggestive of a flaw can be found in this channel. An offset in the absolute mix channel which could be confused as a possible indication is also present. These signals persisted without any significant change even after chemically cleaning the OD and the ID of the tubes. The destructive examination of these intersections showed very minor or no tube wall degradation. Thus, the overall "residuals" of both the differential and absolute mix channels were not indications of tube wall degradation. One needs to examine the detailed structure of the "mix residual" (as outlined in Section A.2.7) in order to assess the possibility that a flaw signal is present in the residual composite. Verification of the integrity of TSP intersections exhibiting alloy property or artifact signals is accomplished by RPC testing of a representative sample of such signals.

A.3.4 Denting and Copper Influences

The Byron and Braidwood Units have not experienced significant corrosion-assisted denting nor do they have reported indications indicative of copper deposits.

A.3.5 RPC Flaw Characterization

The RPC inspection of some support plate intersections with bobbin coil indications > 1.0 volts is recommended in order to verify the applicability of the alternate repair limit. This is based on establishing the presence of ODSCC with minor IGA as the cause of the bobbin indications.

The signal voltage for RPC data evaluation will be based on 20 volts for the 100% throughwall 0.5" long EDM notch at all frequencies.

The nature of the degradation and its orientation (axial or circumferential) will be determined from careful examination of the isometric plots of the RPC data. The presence of axial ODSCC at the support plates has been well documented, but the presence of circumferential indications related to ODSCC at support plate intersections has also been established by tube pulls at two plants. Figures A-16 to A-18 show examples of single and multiple axial ODSCC from Plant S.

Figure A-19 is an example of a circumferential indication related to ODSCC at a tube support plate location from another plant. If circumferential involvement results from circumferential cracks as opposed to multiple axial cracks, discrimination between axial and circumferentially oriented cracking can be generally established for affected arc lengths of about 45 degrees to 60 degrees or larger. Axial cracking has been found by pulled tube exams for RPC arcs of 150 degrees when the axial extent is significant, such as > 0.2 inch.

Pancake coil resolution is considered adequate for separation between circumferential and axial cracks. This can be supplemented by careful interpretation of 3-coil results. Since denting has not occurred at the Byron or Braidwood units, circumferential cracking is not expected to happen.

The presence of IGA as a local effect directly adjacent to crack faces is expected to be indistinguishable from the crack responses and as such of no structural consequence. When IGA exists as a general phenomenon, the eddy current response is proportional to the volume of affected tube material, with phase angle corresponding to depth of penetration and amplitude relatively larger than that expected for small cracks. The presence of distributed cracking, e.g., cellular SCC, may produce responses from microcracks of sufficient individual dimensions to be detected but not resolved by the RPC, resulting in volumetric responses similar to three-dimensional degradation.

For hot leg TSP locations, there is little industry experience on the basis of tube pulls for volumetric degradation, i.e., actual wall loss or general IGA. For cold leg TSP locations, considerable experience is available for volumetric degradation in the form of thinning of peripheral tubes, favoring the lower TSP elevations. Therefore, in the absence of confirmed pulled tube experience to the contrary, volumetric OD indications at hot-leg tube support plates should be considered to represent ODSCC.

A.3.6 Confinement of ODSCC/IGA Within the Support Plate Region

The measurement of axial crack lengths from RPC isometrics can be determined using the following analysis practices. For the location of interest, the low frequency channel (e.g. 10 kHz) is used to set a local scale for measurement. By establishing the midpoint of the support plate response, a reference point for indication location is established. Calibration of the distance scale is accomplished by setting the displacement between the 10 kHz absolute, upper and lower support plate transitions equal to 0.75 inch.

A.3.7 Length Determination with RPC Probes

The number of scan lines indicating the presence of the flaw times the pitch of the rotating probe provides a conservative estimate of crack length which may then be corrected for beam spread.

A.3.8 RPC Inspection Plan

The RPC inspection plan will include the following upon implementation of the APC repair limits:

- Bobbin voltage indications > than 1 volt

- A representative sample of 100 TSP intersections based on the following:

1) Artifact signals (alloy property changes) spanning the range of amplitudes observed during bobbin coil examination

2) Dented tubes at TSP intersections with bobbin dent voltages exceeding 5 volts

3) Bobbin indications less than 1 volt for justification of these indications as typical of ODSCC.

The 100 TSP intersections for RPC inspection would be targeted toward a distribution on the order of 40 dents, 40 artifacts,

artifacts, and 20 indications with bobbin voltages < 1.0 volts; this distribution will be adjusted to reflect field observations as appropriate.

Consideration for expansion of the RPC inspection program would be based on identifying unusual or unexpected indications such as clear circumferential cracks. In this case, structural assessments of the significance of the indications would be used to guide the need for further RPC inspection.

A.3.8.1 3-coil RPC Usage

It is Commonwealth Edison's standard practice to use 3-coil RPC probes, incorporating a pancake coil, an axial preference coil, and a circumferential preference coil. Comparisons for ODSCC with bobbin amplitudes exceeding 1.0 volts have shown that the pancake coil fulfills the need for discrimination between axial and circumferential indications, when compared against the outputs of the preferred direction coils. Pancake coils have been the basis for reporting RPC voltages for model boiler and pulled tube indications in the APC database; these data permit semi-quantitative judgments on the potential significance of RPC indications. The requirements for a pancake coil is satisfied by the single coil, 2-coil, and 3-coil probes in common use for RPC inspections.

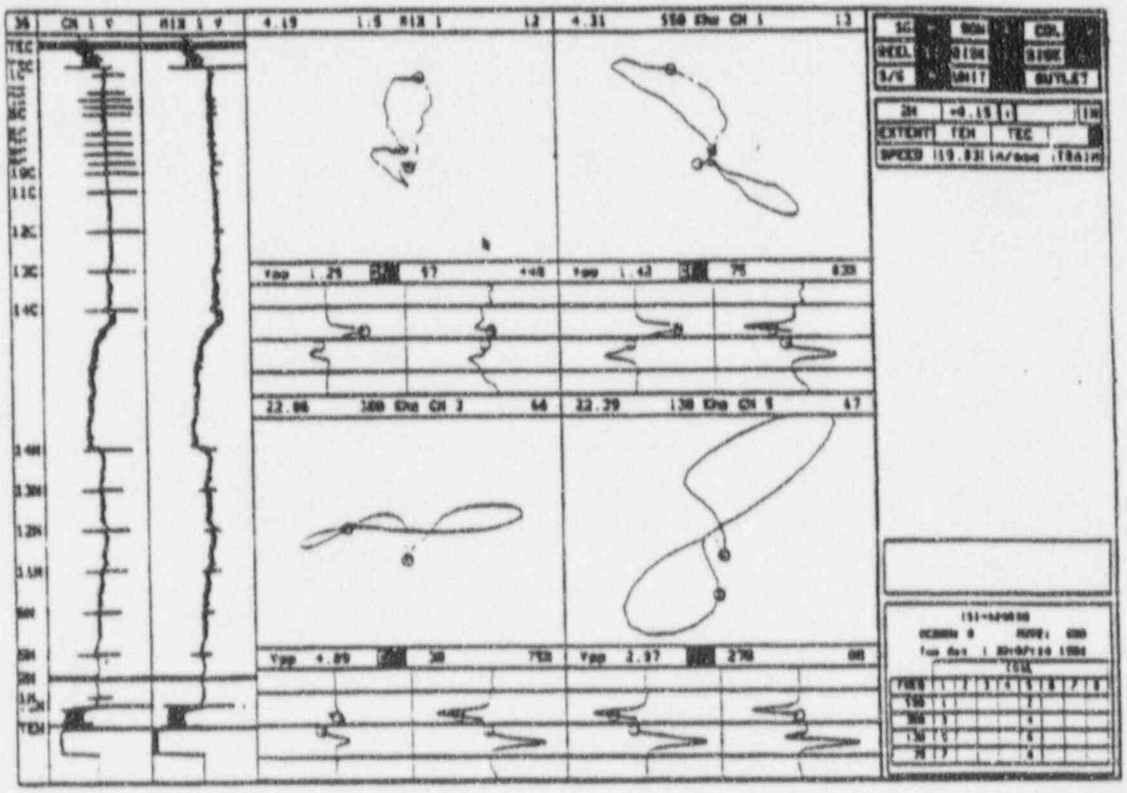

Figure A-2. Bobbin Coil Amplitude Analysis of ODSCC at TSP.

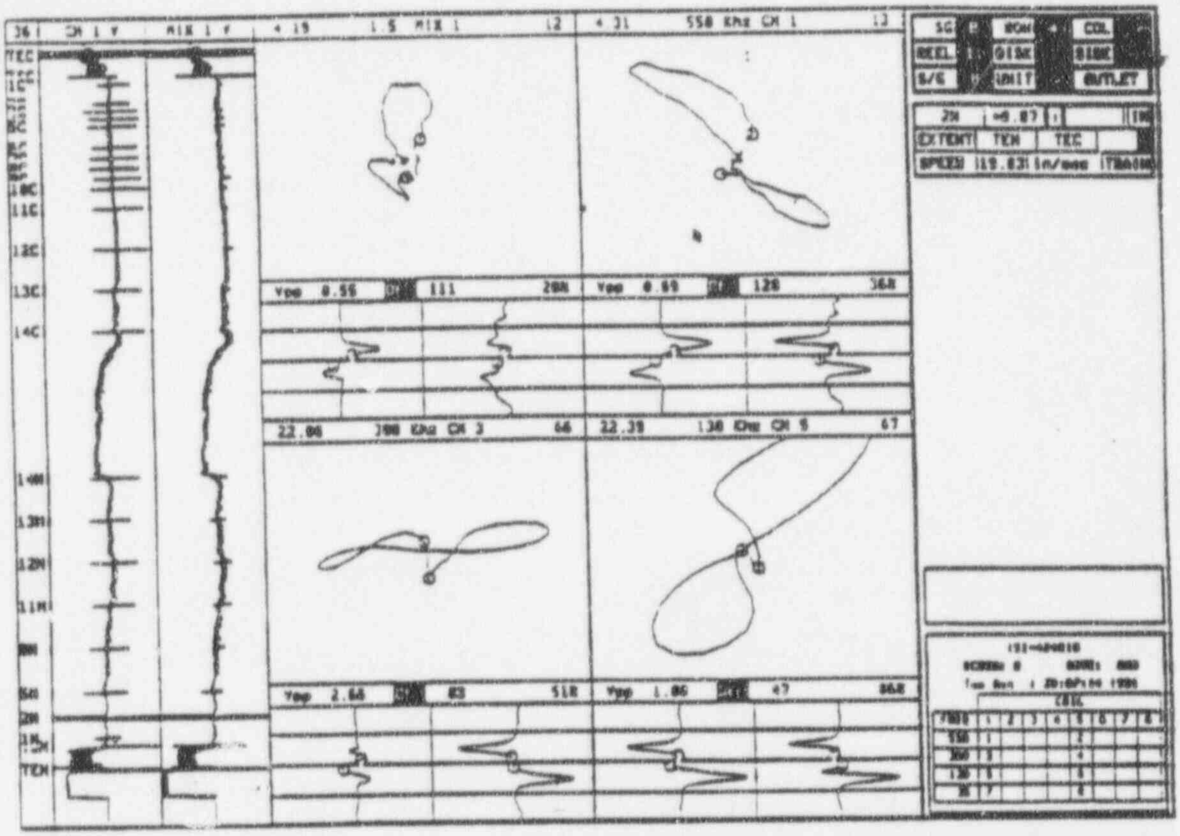

Figure A-3. Bobbin Coil Amplitude Analysis of ODSCC Indication at TSP - Improper Identification of Full Flaw Segment Resulting in Reduced Voltage Measurement When Compared with Figure A-2.

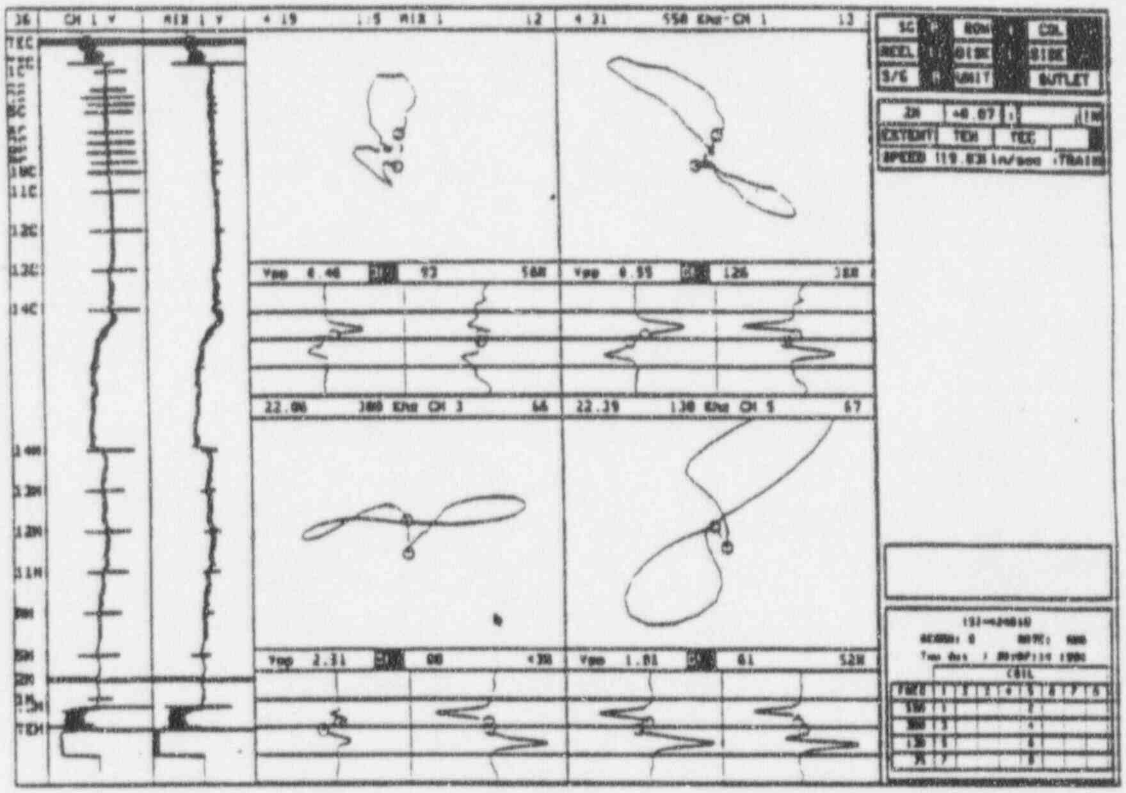

Figure A-4. Bobbin Coil Amplitude Analysis of ODSCC Indication at TSP - Improper Identification of Full Flaw Segment Resulting in Reduced Voltage Measurement When Compared to Figure A-2.

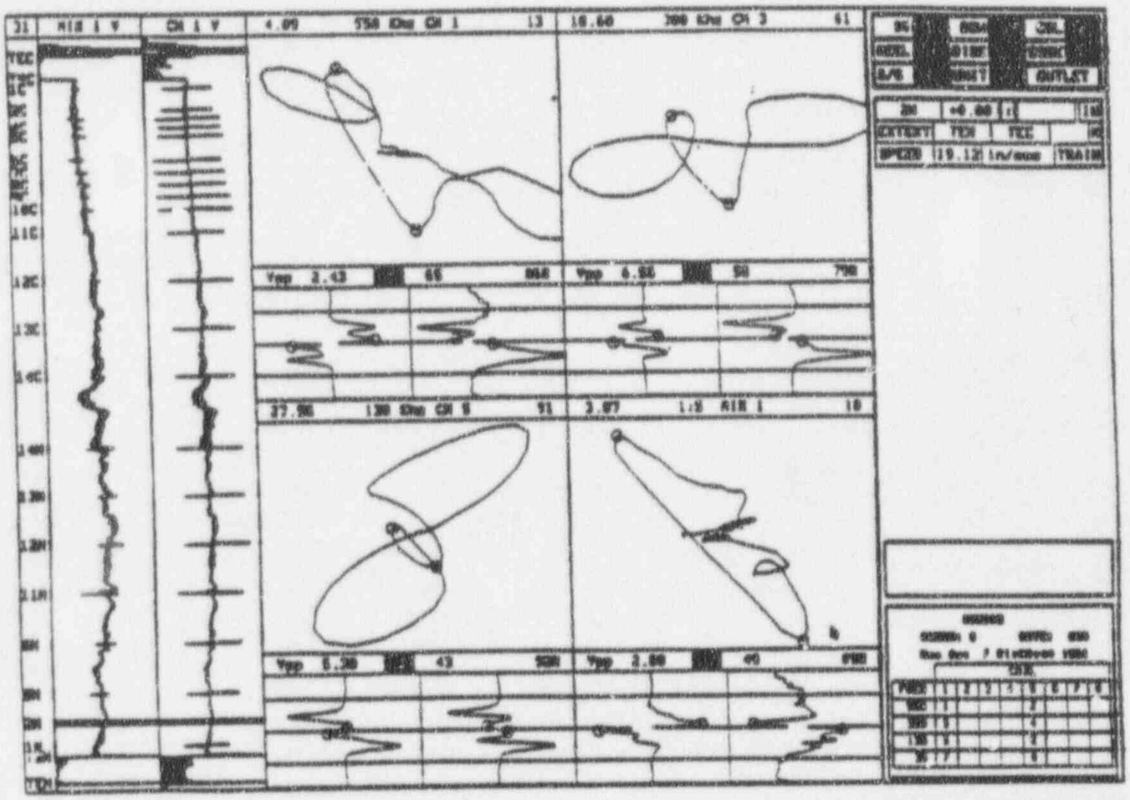

Figure A-5. Correct Placement of Voltage Set Points on Mix 1 Lissajous Traces for R18C103.

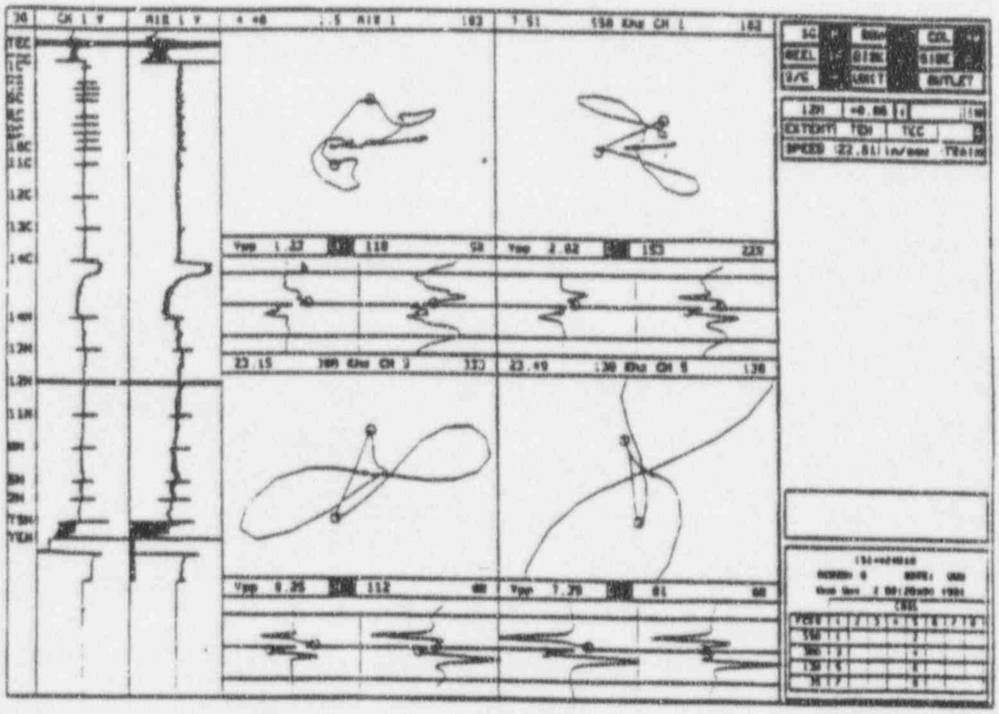

Figure A-6. Correct Placement of Vector Dots on Mix 1 Lissajous Traces for R22C40.

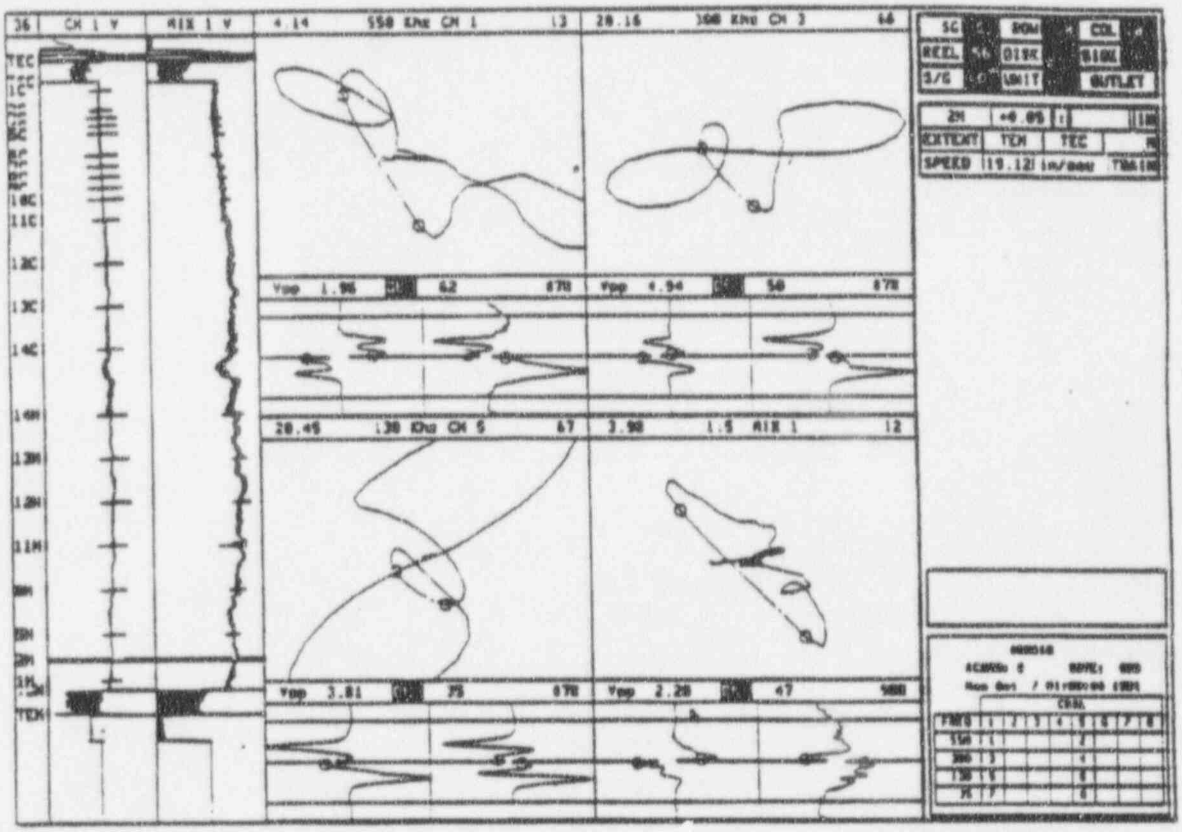

Figure A-7. Incorrect Placement of Vector Dots on Mix 1 Lissajous Traces for R18C103.

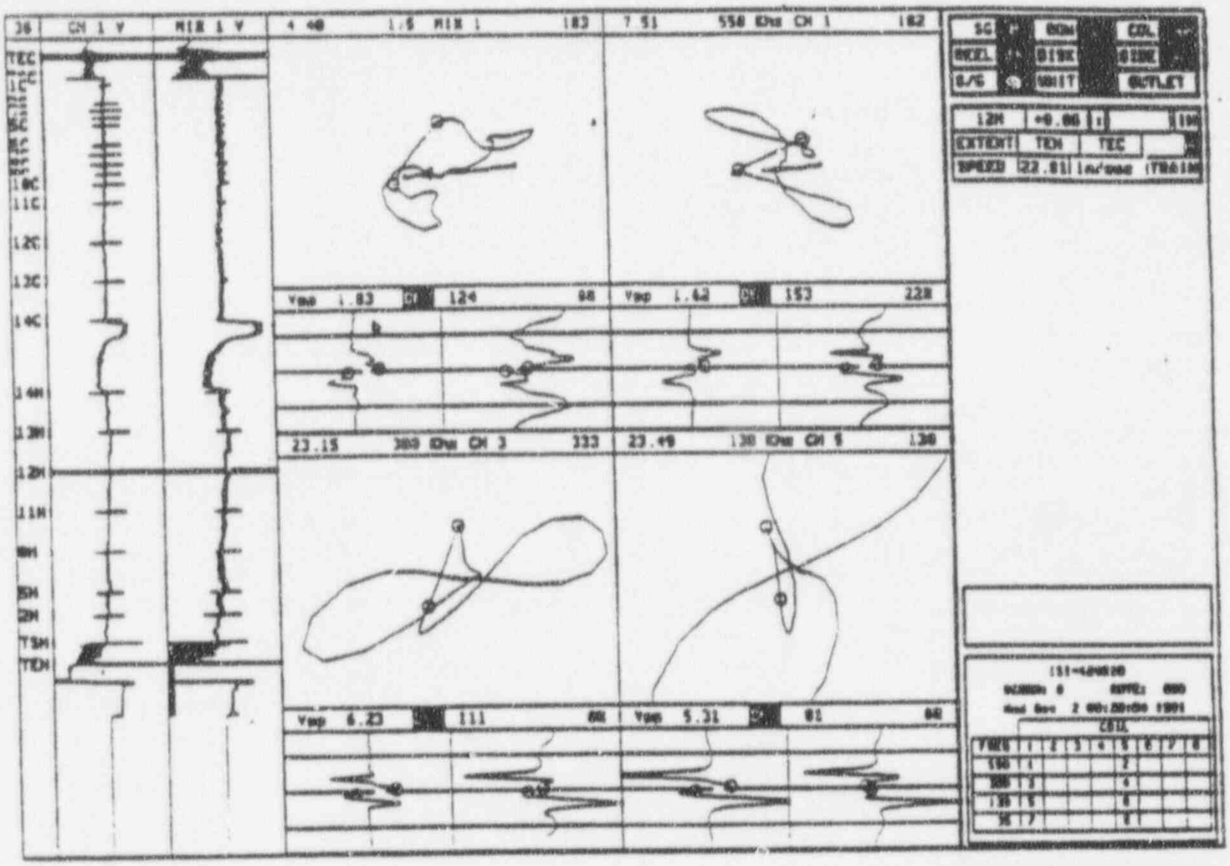

Figure A-8. Incorrect Placement of Vector Dots on Mix 1 Lissajous Traces for R22C40.

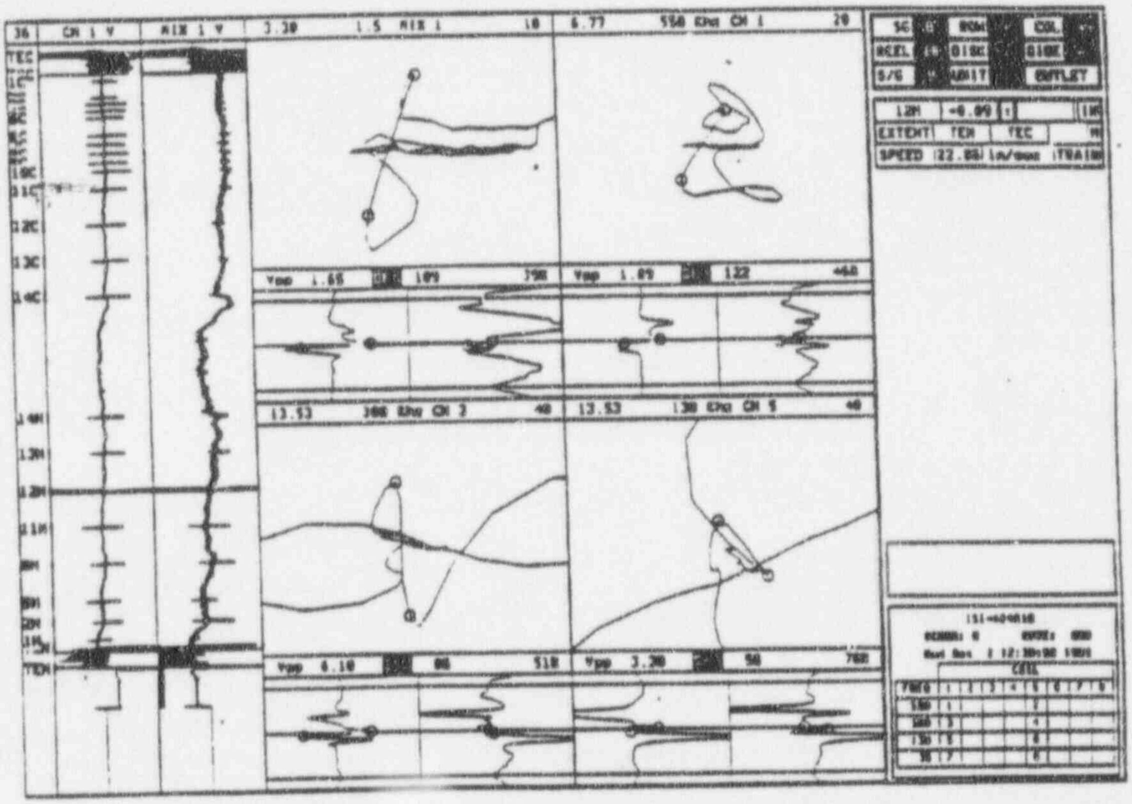

Figure A-9. Incorrect Maximum Voltage Derived from Placement of Vector Dots on Transition Region of 550 kHz Raw Frequency Data Lissajous Trace for R42C44.

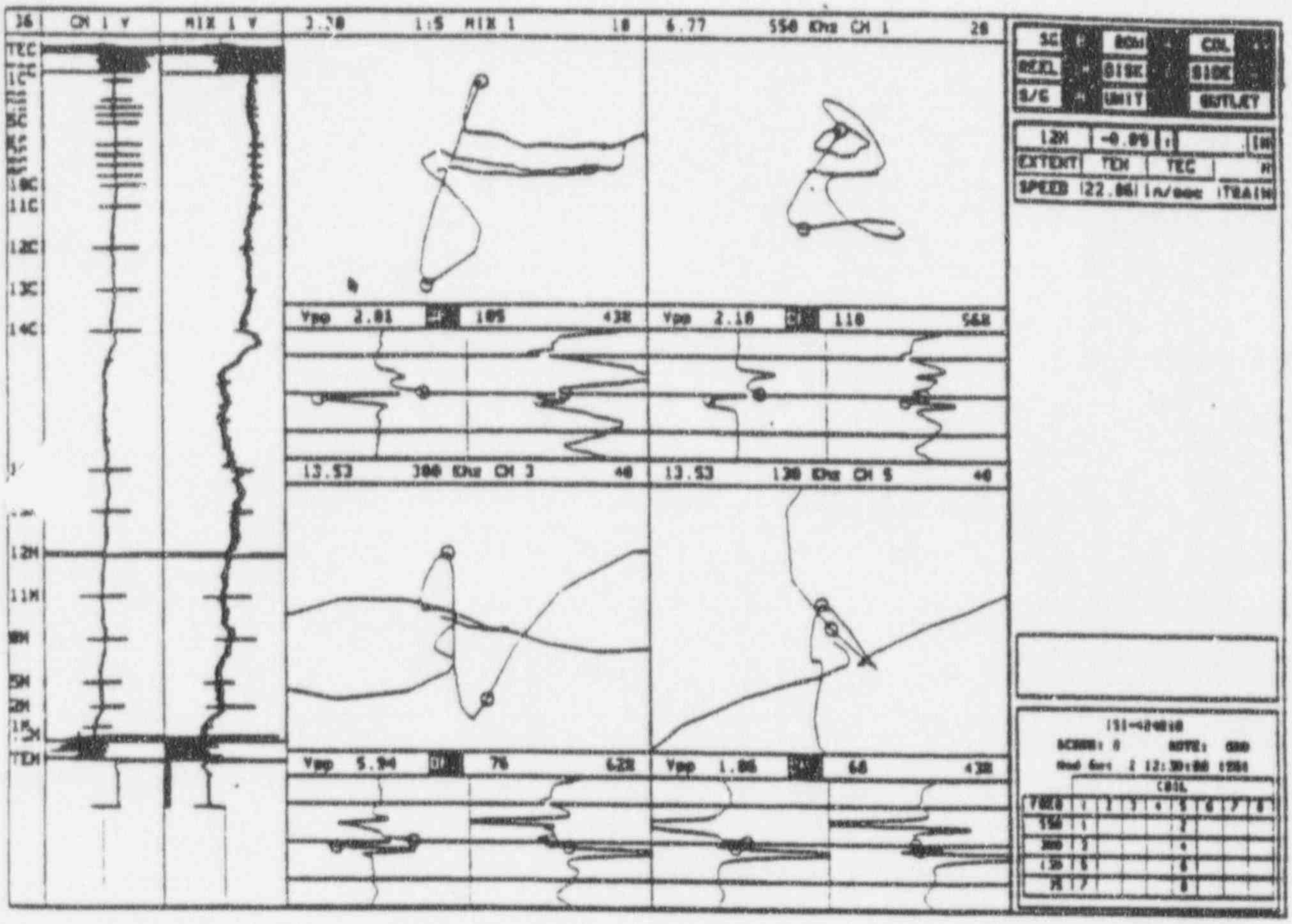

Figure A-10. Correct Placement of Vector Dots on Mix 1 Lissajous Figure for R42C44.

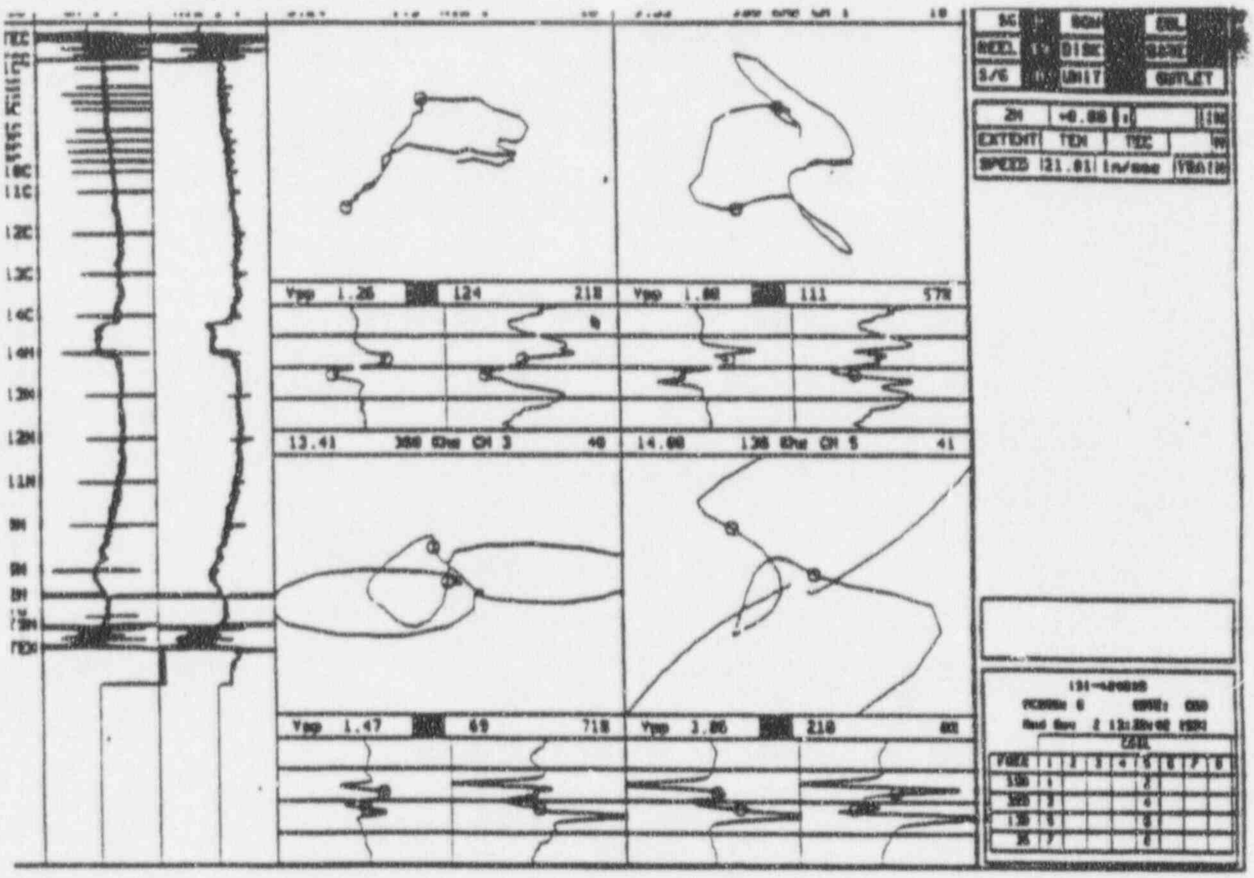

Figure A-11. Placement of Vector Dots Based Solely on Mix 1 Lissajous Figure (no significantly sharp transitions in any of the raw frequencies) - R10C44.

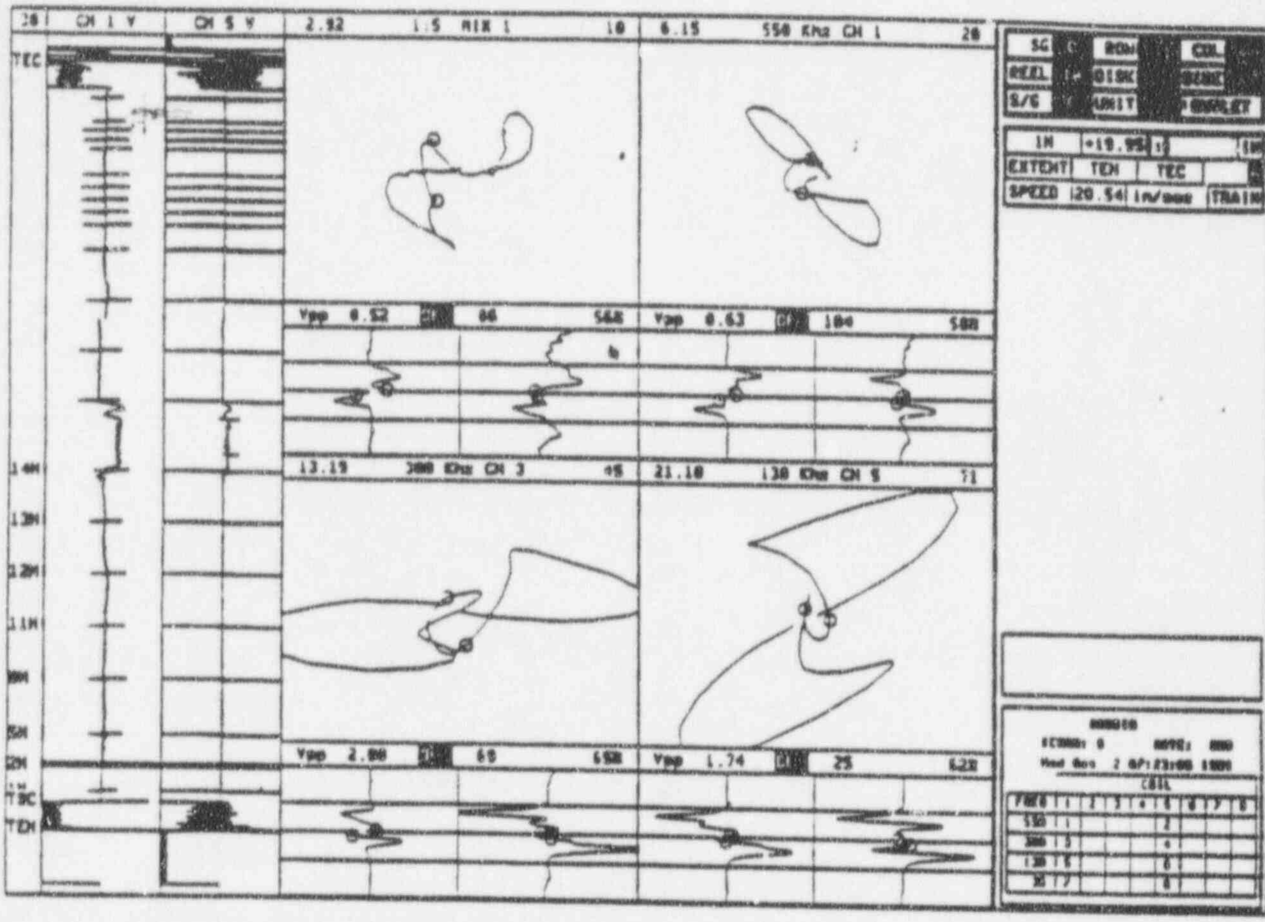

Figure A-12. Placement of Dots Marking Mix 1 Lissajous Figure for R16C26.

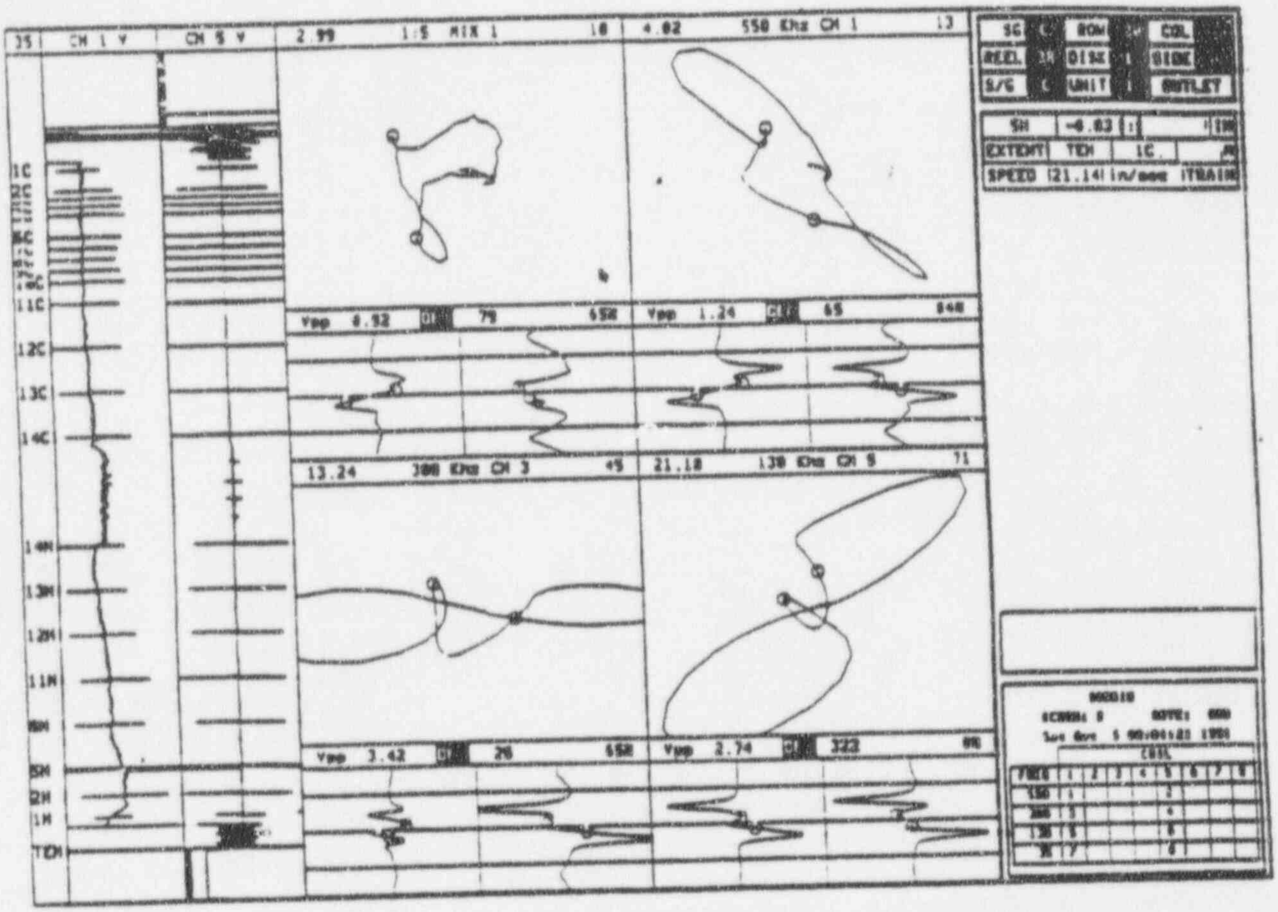

Figure A-13. Incorrect Placement of Vector Dots Marking Mix 1 Lissajous Figure for R30C74.

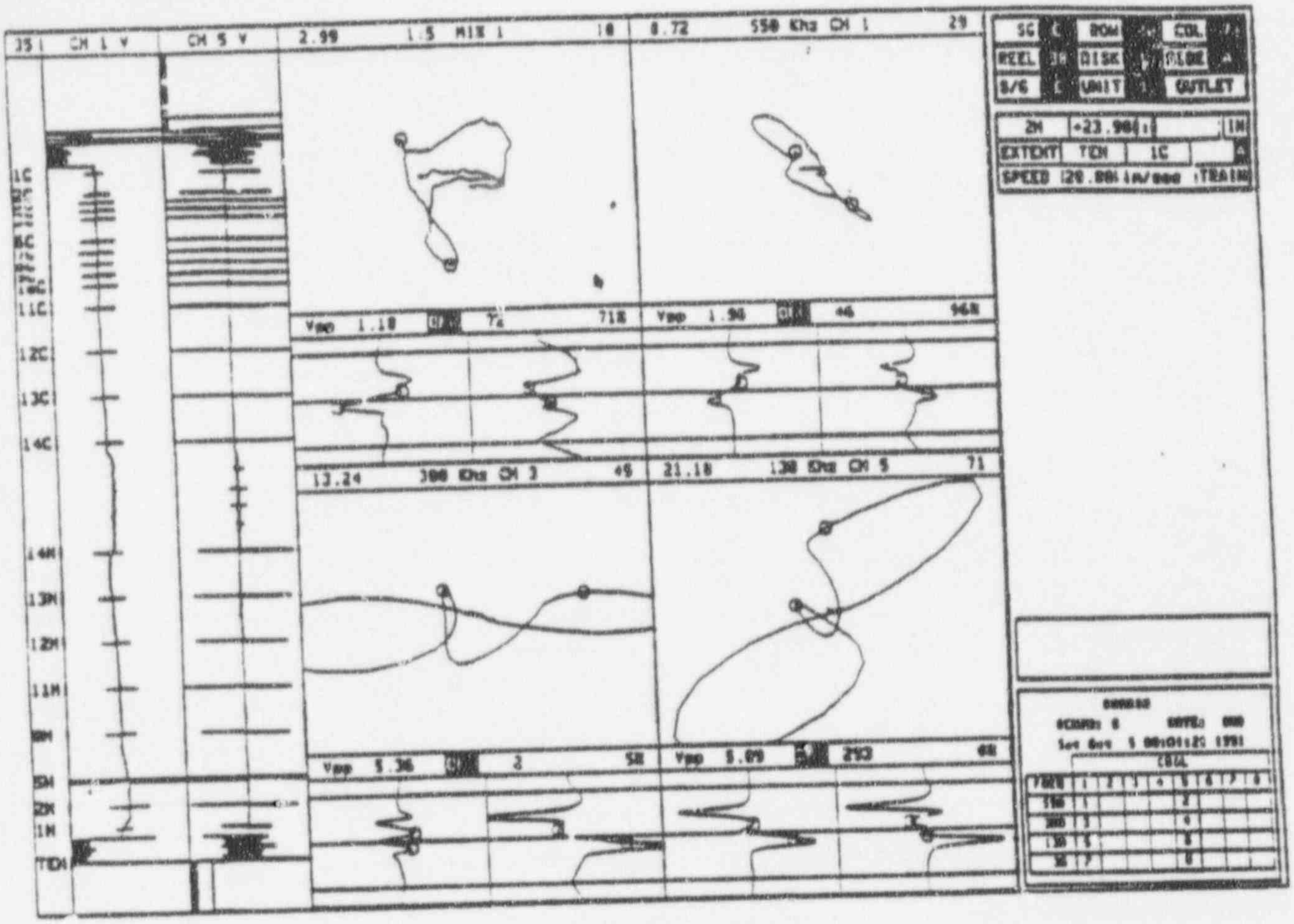

Figure A-14. Correct Placement of Dots to Effect Maximum Voltage - R30C74.

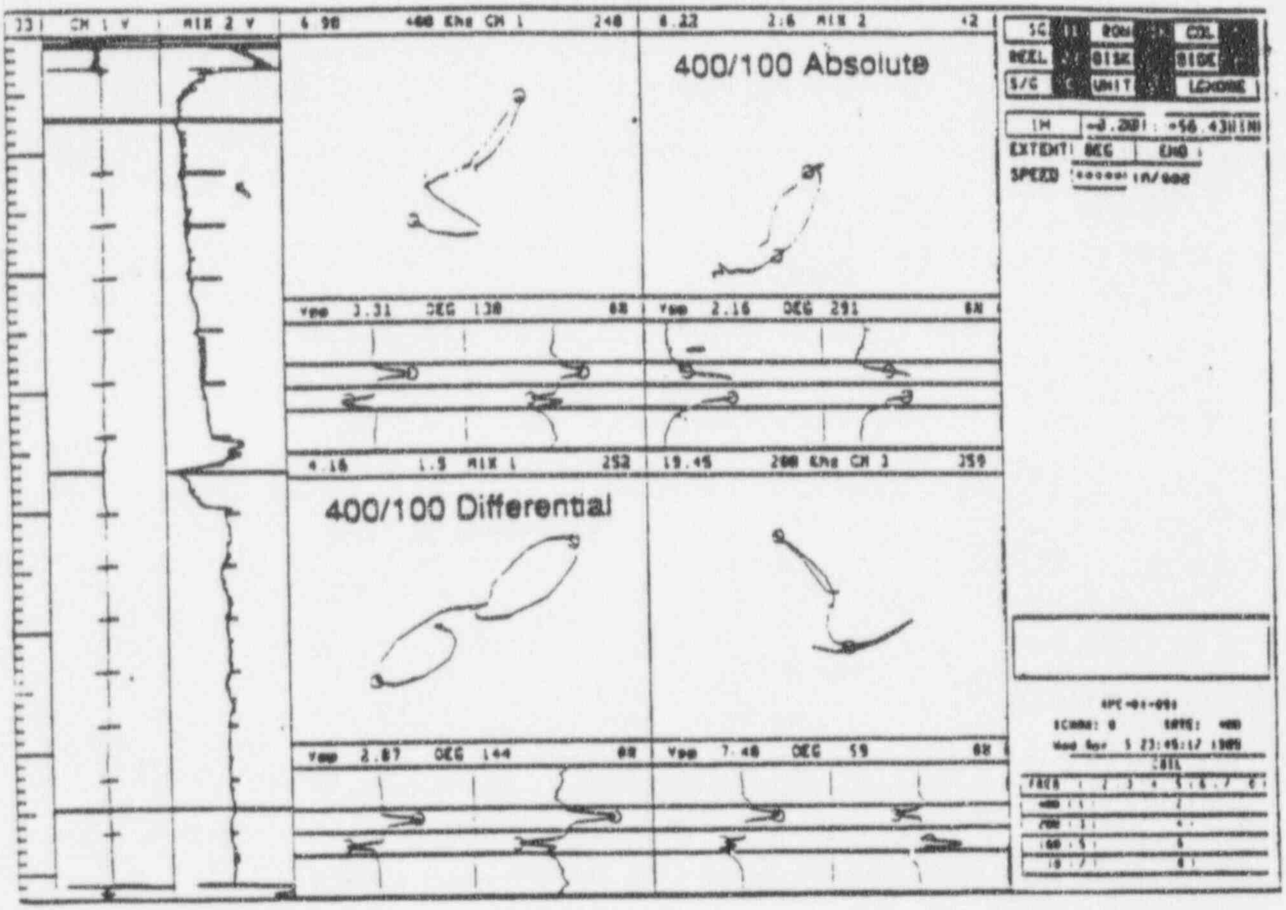

Figure A-15. Example of Bobbin Coil Field Data - Mix Residual Due to Alloy Change.

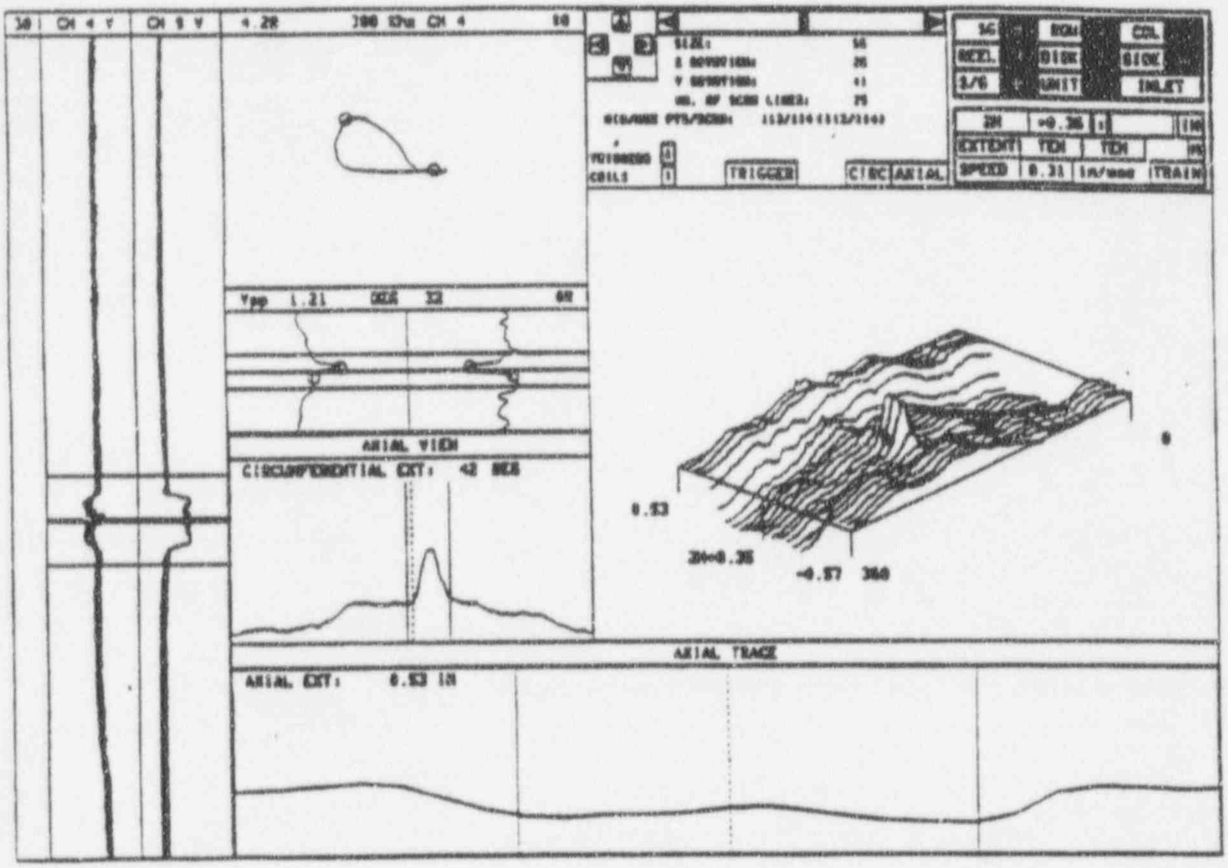

Figure A-16. Example of RPC Data for Single Axial Indication (SAI) Attributed to ODSCC - Plant S.

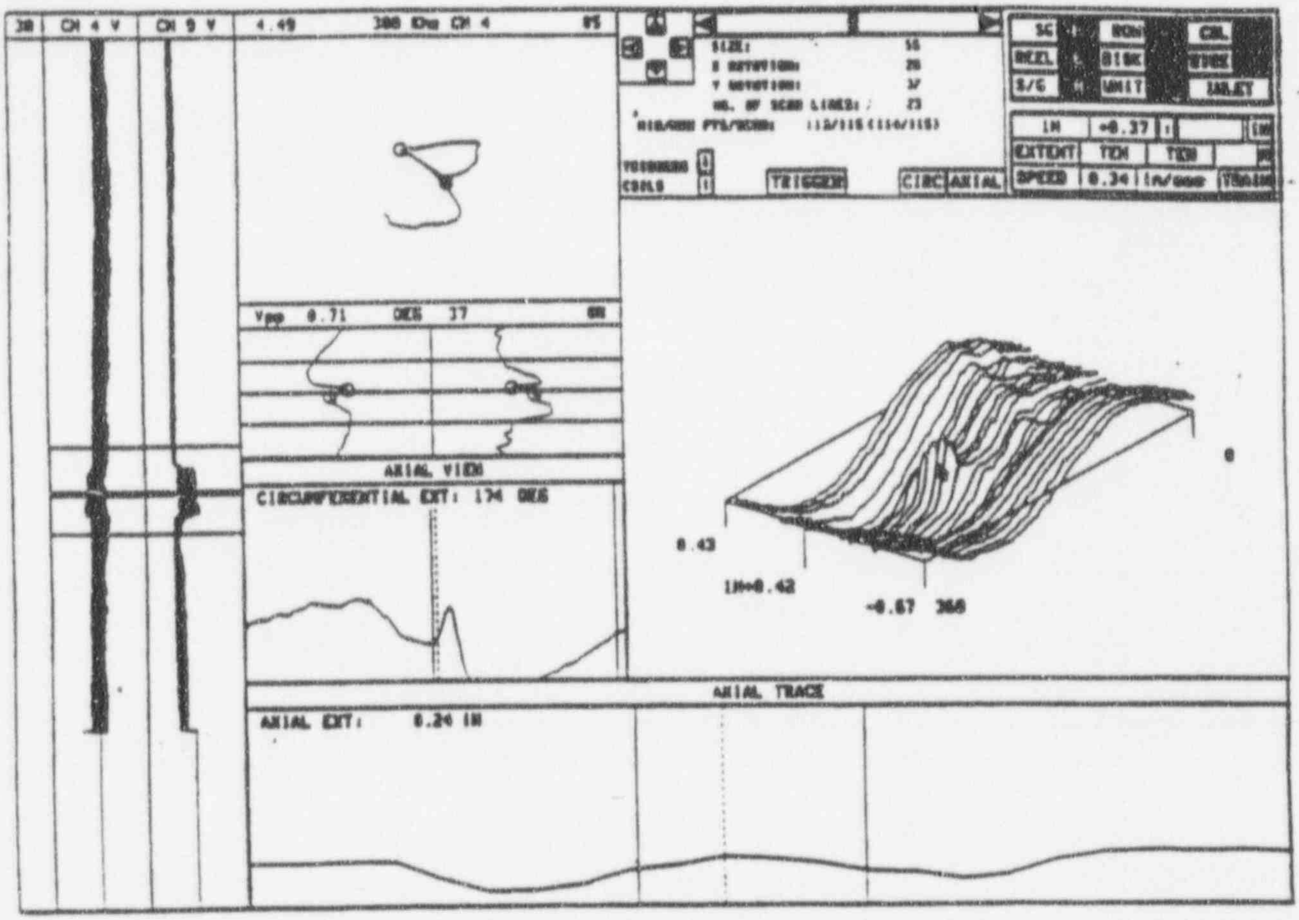

Figure A-17. RPC Data for Single Axial ODSCC Indication(SAI) - Plant S.

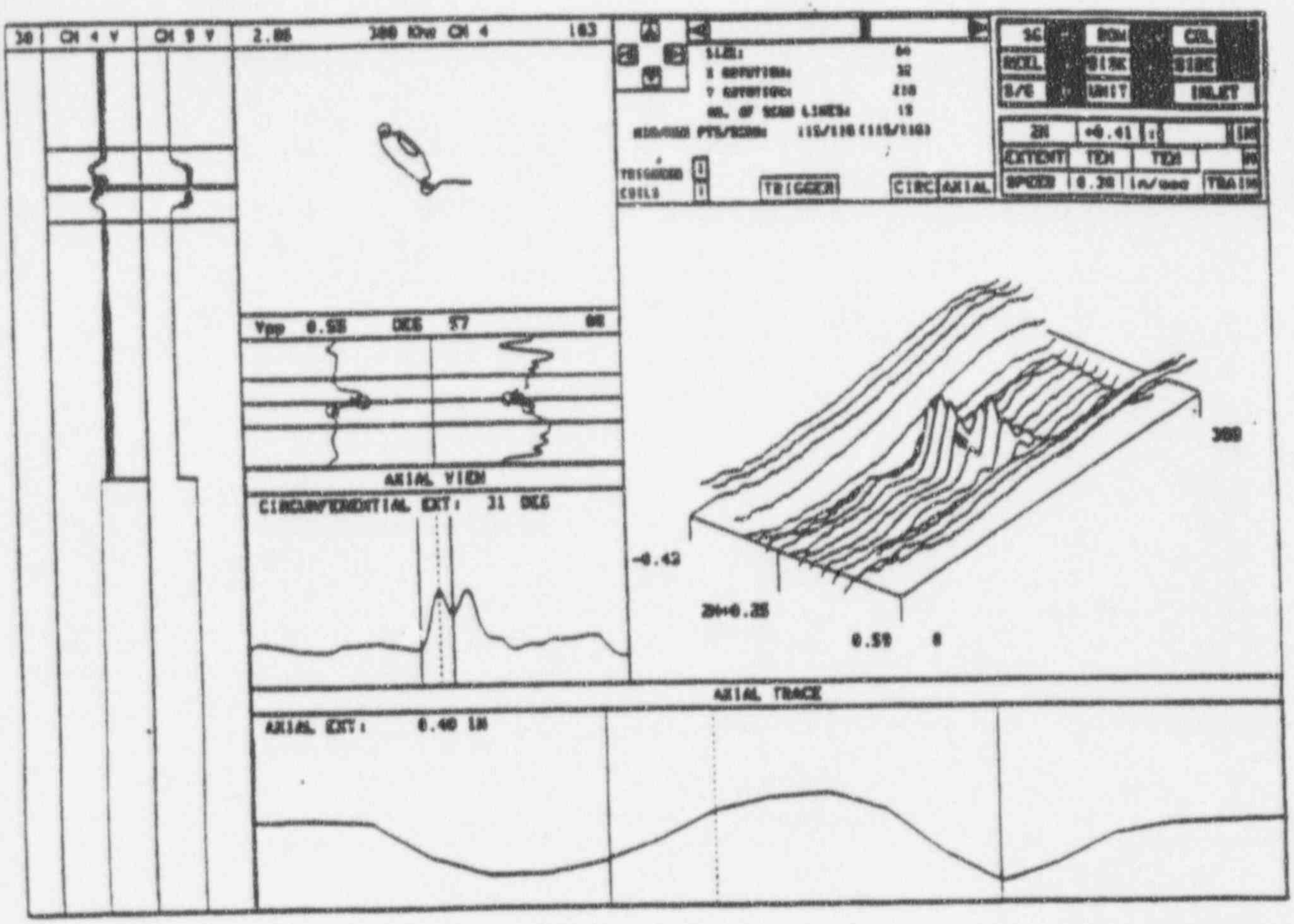

Figure A-18. RPC Data for Multiple Axial ODSCC Indications (MAI) - Plant S.

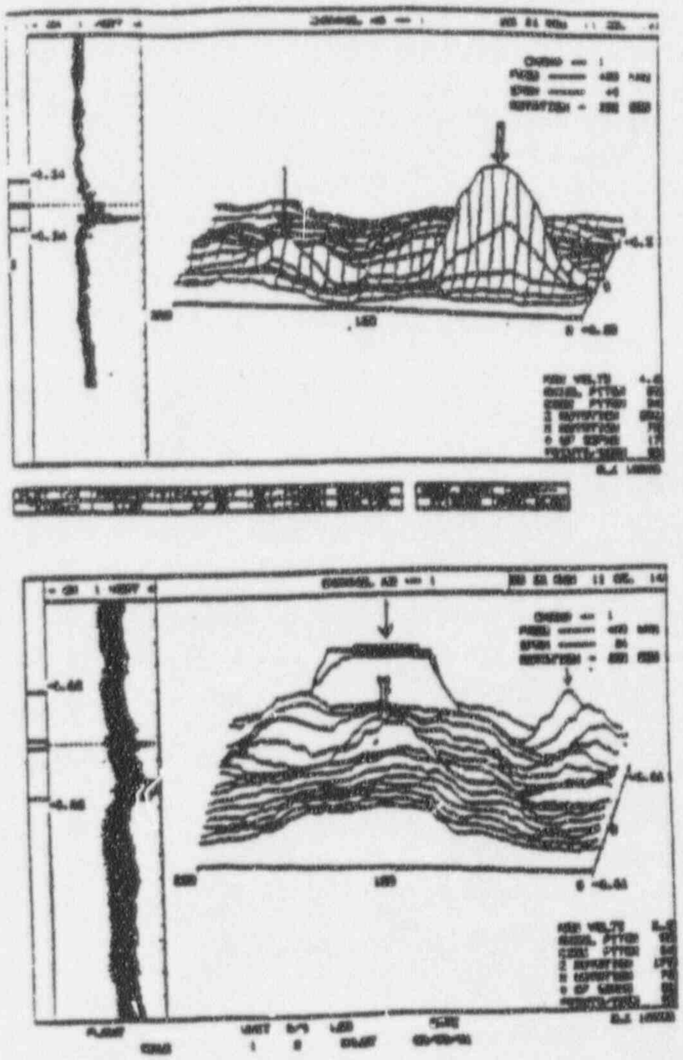

Figure A-19. RPC Data for Circumferential ODSCC Indications at Dented Upper and Lower TSP Edges.

APPENDIX B

ANALYSIS GUIDELINES CHANGE FORMS

APPENDIX B
ANALYSIS GUIDELINES CHANGE FORMS
(PAGE 1 0F 2)

ANALYSIS GUIDELINES CHANGE FORM

Subject:

DESCRIPTION OF CHANGE:

REASON FOR CHANGE:

TECHNICAL BASIS:

EXAMINATION IMPACT:

AUTHORIZATIONS:

Lead Analyst_______________ _________________________ Date: _____/_____/_____

CECO Acknowledgment____________________ ___________ Date _____/_____/_____

APPENDIX B
ANALYSIS GUIDELINES CHANGE FORMS
(PAGE 2 0F 2)

ANALYSIS GUIDELINES CHANGE ACKNOWLEDGMENT FORM

Change Notice # :

EFFECTIVE DATE OF CHANGE ___/__ _/___ TIME ___/___ am pm

Analyst Signature	Date	Time
________________	___/___/___	__:__
________________	___/___/___	__:__
________________	___/___/___	__:__
________________	___/___/___	__:__
________________	___/___/___	__:__
________________	___/___/___	__:__
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________________	___/___/___	__:__
________________	___/___/___	__:__
________________	___/___/___	__:__
________________	___/___/___	__:__

APPENDIX C

ANALYSIS & RETEST CODES

Appendix C
(Page 1 of 2)

Analysis & Retest Codes

Category 1 - No Further Action		Analysis	Retest
	No Detectable Degradation	NDD	RND
	Plugged	PLG	-
	Sleeved	SLV	RSV
	Positive Indentification	PID	-
Category 2 - Possible Flaw, Further Action Required			
	Non-quantifiable Indication	NQI	RNQ
	Absolute Drift Indication	ADI	RAD
	Distorted Support Indication	DSI	RDI
	Distorted Tubesheet Indication	DTI	RTI
	Distorted Roll Indication	DRI	RTI
	Single Axial Indication	SAI	RSA
	Multiple Axial Indications	MAI	RMA
	Single Circumferential Indication	SCI	RSC
	Multiple Circumferential Indications	MCI	RMC
	Mixed-Mode Indications	MMI	RMI
	Free-Span Signal	FSS	RSS
	Free-Span Indication	FSI	RSI
	Lead Analyst Resolution	LAR	RAR
Category 3 - Possible Loose Part, Further Action Required			
	Possible Loose Part	PLP	RLP
Category 4 - Further Action Required, Retest Condition			
	Bad Data	RBD	RBD
	Incomplete Test	INC	RIC
	Obstructed	OBS	ROB
	Template Plug	TMP	RTP
	Tube No Test	TNT	RNT
	To Be Retested	TBR	-
	Fixture	FIX	RFX
	Tube Number Check	TNC	RNC

Appendix C
(Page 2 of 2)

Analysis & Retest Codes (Cont'd)

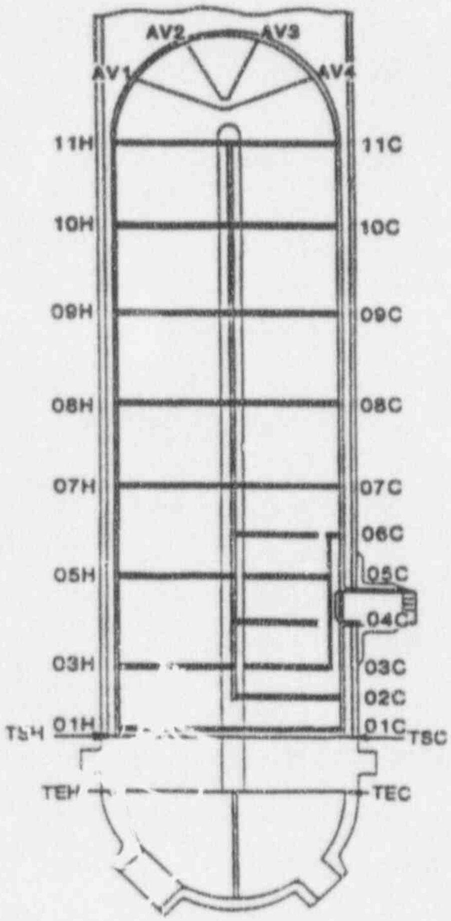
Category 5 - No Further Action Required		Analysis	Retest
	Bulge	BLG	RBL
	Copper Deposit	CUD	RCD
	Dent	DNT	RDN
	Deposit	DEP	RDP
	Ding	DNG	RDG
	Distorted Roll Transition Signal	DRT	RRT
	Distorted Support Plate Signal	DSS	RDS
	Distorted Tubesheet Signal	DTS	RDT
	Expansion	EXP	REX
	Indication Not Reportable	INR	RNR
	Indication Not Found	INF	RNF
	Manufacturing Burnish Mark	MBM	RBM
	Manufacturing Anomaly Mark	MAM	RAM
	Noisy Tube	NSY	RSY
	Over Roll	OVR	RVR
	Overexpansion	OXP	RXP
	Partial Tubesheet Expansion	PTE	RTE
	Permeability Variation	PVN	RPV
	Skipped Roll	SKR	RSR
	Sludge	SLG	RSG
	Top Main Roll	TMR	RTM
	Volumetic Indication (s)	VOL	RVL
	Free-Span Differential	FSD	RSD
	Shot Peening Anamoly	SPA	RPA

APPENDIX D

SUPPORT STRUCTURES NOMENCLATURE AND MEASUREMENTS

Appendix D
Support Structures Nomenclature and Measurements
(Page 1 of 3)

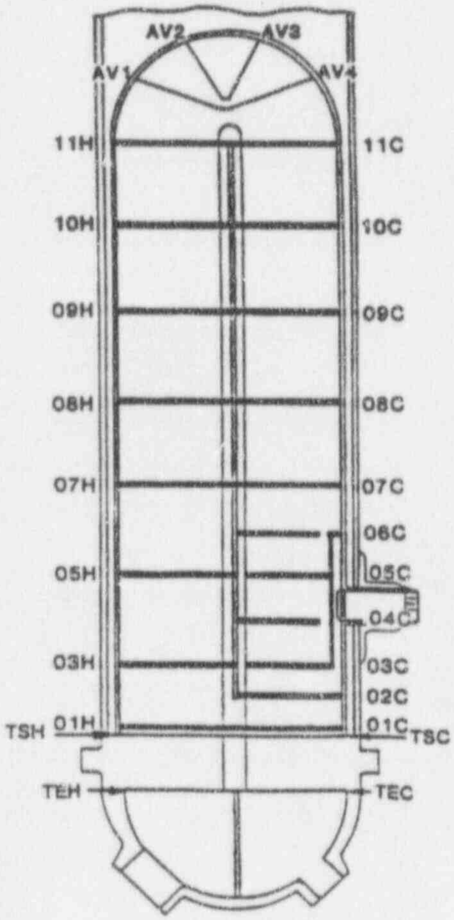
Westinghouse Model D4 S/G
Support Structures Measurements



Level	Elevation Spacing (inches)	
	Hot-leg	Cold-leg
Tube End	0	0
Tubesheet top	21.2	21.2
Center of 1st structure	6.4	6.4
Center of 2nd structure	-	12
Center of 3rd structure	30	18
Center of 4th structure	-	18
Center of 5th structure	36	18
Center of 6th structure	-	18
Center of 7th structure	36	18
Center of 8th structure	43	-
Center of 9th structure	43	-
Center of 10th structure	43	-
Center of 11th structure	43	-

Appendix D
Support Structures Nomenclature and Measurements
(Page 2 of 3)

Westinghouse Model D5 S/G
Support Structures Measurements



Level	Elevation Spacing (inches)	
	Hot-leg	Cold-leg
Tube End	0	0
Tubesheet top	21.2	21.2
Center of 1st structure	6.4	6.4
Center of 2nd structure	-	12
Center of 3rd structure	28	18
Center of 4th structure	-	18
Center of 5th structure	36	18
Center of 6th structure	-	18
Center of 7th structure	36	18
Center of 8th structure	43	-
Center of 9th structure	43	-
Center of 10th structure	43	-
Center of 11th structure	43	-

Appendix D
Support Structures Nomenclature and Measurements
(Page 3 of 3)

Structures Nomenclature

Notation	Description
TEH	Tube end hot
TSH	Top of tubesheet - hot leg
01H	1st support plate - hot leg
03H	3rd support plate - hot leg
05H	5th support plate - hot leg
07H	7th support plate - hot leg
08H	8th support plate - hot leg
09H	9th support plate - hot leg
10H	10th support plate - hot leg
11H	11th support plate - hot leg
AV1	1st anti-vibration bar
AV2	2nd anti-vibration bar
AV3	3rd anti-vibration bar
AV4	4th anti-vibration bar
11C	11th support plate - cold leg
10C	10th support plate - cold leg
09C	09th support plate - cold leg
08C	08th support plate - cold leg
07C	07th support plate - cold leg
06C	06th support plate - cold leg
05C	05th support plate - cold leg
04C	04th support plate - cold leg
03C	03th support plate - cold leg
02C	02th support plate - cold leg
01C	01st support plate - cold leg
TSC	Top of tubesheet - cold leg
TEC	Tube end cold

ATTACHMENT J

REFERENCES

1. Regulatory Guide 1.121, "Basis for Plugging Degraded PWR Steam Generator Tubes," Revision 0, August 1976 (issued for comment)

2. Draft NUREG-1477, "Voltage-Based Interim Plugging for Steam Generator Tubes-Task Group Report," June 1, 1993

3. EPRI Draft Report NP-6864-L, "PWR Steam Generator Tube Repair Limits: Technical Support Document for Expansion Zone PWSCC in Roll Transitions " Revision 2, August 1993

4. EPRI Draft Report TR-100407, "PWR Steam Generator Tube Repair Limits - Technical Support Document for Outside Diameter Stress Corrosion Cracking at Tube Support Plates," Revision 1, August 1993

5. Westinghouse Letter Report NSD-TAP-3069, "Braidwood 1: Technical Support for Cycle 5 S/G Interim Plugging Criteria, Pre-WCAP Release," April 21, 1994

6. Westinghouse Letter CAE-94-200, "Byron Unit 1: Steam Generator Plugged Tube Growth Data," July 29, 1994