B&W NUCLEAR TECHNOLOGIES
Special Products & Integrated Services

CRYSTAL RIVER

UNIT #3

EDDY CURRENT DATA

ANALYSIS GUIDELINES

DRAFT

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1.0 Introduction

1.1 Purpose

The purpose of this document is to establish guidelines that are to be used by personnel performing eddy current data analysis at Crystal River Unit #3. This guideline was developed to establish consistency in the analysis process and to ensure that the results of the analysis are in compliance with requirements of Florida Power Corporation.

B&W Nuclear Technologies technical procedure ISI-460 shall govern the evaluation and reporting of eddy current data for nonferromagnetic steam generator tubing. All requirements specified in this guideline are in addition to those specified by ISI-460.

1.2 References

ASME Boiler and Pressure Vessel Code Section XI, 1983 Edition, Summer 1983 Addenda.

PWR Steam Generator Examination Guidelines, NP-6201, Revision 2, December 1988, Electric Power Research Institute, Table 4-7, and Appendix D.

American Society of Nondestructive Testing SNT-TC-1A 1975 Edition.

Crystal River 3 Technical Specification 4.4.5/SP-305, OTSG Inservice Inspection.

2.0 Crystal River Unit#3 Steam Generator Characteristics

860 MWe Pressurized Water (PWR) Babcock & Wilcox 2 Loop Nuclear Steam Supply System (NSSS).

Steam Generators are Babcock & Wilcox Once-Through (OTSG) containing 15,531 tubes per generator.

Tubing material is annealed CrFeNi alloy Inconel 600 with .625" OD and .034" nominal wall thickness that has a sensitized micro-structure resulting from the post-fabrication stress relief heat treatment.

The tubesheets are open crevice type with a 1" to 2" hard roll near the tube ends.

The outer periphery 15S tube support plate (TSP) (2 or 3 tubes in toward the tube bundle center) are 1.50" drilled carbon steel. All other TSP's are 1.50" broached carbon steel.

The "B" OTSG UTS tube ends were severely damaged in 1978 from a loose burnable poison rod assembly (BPRA).

3.0 Operating History at Crystal River Unit #3

3.1 Crystal River Unit 3 began its 9th fuel cycle in July 1992. When fuel cycle 9 is completed on April 7th, CR-3 will have 10.2 EFPY of operation. At the completion of the eddy current examination of the two steam generators in Refuel 8 the following number of tubes were plugged.

Steam Generator	A	B
Total Tubes Plugged	42	120

3.2 Several areas where indications are developing in the A-OTSG include: wear in the lane region at the 15S TSP, wear in the periphery region at the 08S, 09S and 10S TSP's, and an unknown damage mechanism at the 07S and 08S TSP's. For the B-OTSG, the areas include: wear in the lane region at the 15S TSP, and an unknown damage mechanism in the periphery region of the 09S, 10S and at the 07S and 08S TSP's.

Emerging Areas of Interest

Areas with significant eddy current OD general, OD wear, and ding indications for the most recent refueling outage examination of the A-OTSG and B-OTSG are identified.

A-OTSG

OD wèar indications in the periphery region at the 08S, 09S, and 10S TSP's, and in the lane region at the 15S TSP.

OD general indications in the interior region at the LTS-1st span.

B-OTSG

OD general indications in the periphery region at the 07S and 09S TSP's.

OD general indications in the interior region at t LTS-1st span and at the 07S TSP.

OD general indications in the lane region at the UTS.

OD wear indications in the periphery region at the 08S and 09S TSP's.

Ding indications in the lane region at the UTS and LTS.

These are the most prevalent problems occurring at Crystal River Unit 3. However, the following regions and their associated damage mechanisms within OTSG's are also areas of concern.

3.3 High Cycle Fatigue - OD circumferential cracking occurring in the vicinity of the 15S TSP or upper tubesheet secondary face in the open lane/wedge region. The initiating mechanism for high cycle fatigue is believed to be a combination of surface damage from corrosion, fretting and high crossflow velocities. This type of flaw has been the cause of numerous unscheduled leaker outages. This problem has been addressed by sleeving the tubes in question from the upper tubesheet roll to just below the 15S TSP.

3.4 Impingement Erosion - An erosion/corrosion type discontinuity occurring from the flow of secondary side water with contaminants or debris entrapped in the secondary side water fluid steam. This will cause tube wall loss just above the affected TSP. It generally occurs at or above the upper TSP's (10S TSP and above) in tubes near the outer periphery.

3.5 Wear - Wear fretting has occurred at TSP intersections in tubes near the periphery of the tube bundle. Wear may be flat or tapered, and may occur at one or more of the broached TSP contact areas or at drilled hole locations; it is generally detected at the upper TSP's (09S TSP through the 15S TSP).

3.6 Manufacturing Buff Marks (MBM) - So called buff marks are the result of final hand polishing or grinding operations on tubing during manufacturing. Polishing or grinding may also cause cold working which can result in permeability changes in the tubing. This type of indication may occur anywhere on the tube. Buff mark indications typically have a strong absolute coil response with an axial extent on the order of an inch or so. The differential coil response is usually not pronounced or evident at all; although when present the indication may measure deep.

3.7 Other Types of Degradation - Some small and large amplitude signals have been observed in the boiling region of the tube bundle. These are typically multiple, small amplitude signals within a couple of inches of each other along the tube length. The majority of these indications were found between the LTS and the eighth tube support plates.

The defects responsible for the low voltage eddy current signals in the first span region consisted of small, relatively shallow, isolated patches of OD-initiated IGA. The IGA damage was associated with a non-uniform deposit pattern, concentrated in an area 8 to 18 inches above the secondary face of the lower tube sheet. The corrosion was attributed to low-temperature, reduced-sulfur attack, which probably occurred early in plant life and is no longer active. The bobbin coil eddy current technique was successful in detecting this damage, detecting all IGA patches with depths greater than 50% through wall and ~80% of those with depths equal to or greater than 40% throughwall. Additionally, lab tests determined that the IGA had almost no effect on the burst strength of the tubing.

3.8 IGA - Secondary side initiated intregranular attack (IGA) has been identified in the upper spans and within the upper tubesheet. Generally these indications have been seen in the lane and wedge regions of OTSG tubing.

4.0 Data Analysis Equipment

4.1 Hardware and Software Requirements

The equipment, material and document requirements are governed by the nature of the job, plant request and procedural requirements.

4.2 Examination Frequencies

600 kHz Differential - This is the inspection frequency to satisfy the ASME code requirements. This requires a phase angle between 50 degrees to 130 degrees from the signal of the 100% through wall hole to the signal from the four 20 percent flat bottom holes, rotating clockwise.

600 kHz Absolute - Defect confirmation and TS profiling.

400 kHz Differential - Used for defect detection and confirmation.

400 kHz Absolute - Defect confirmation.

200 kHz Differential - Used for a mix component (TSP suppression) and defect confirmation.

200 kHz Absolute - Defect confirmation.

35 kHz Differential - Used for structure locating.

35 kHz Absolute - Used for structure locating and sludge or debris measurements. (See Attachment #1 for location of structures).

4.3 Frequency Mixes

Mix #1 - 600/200 Differential - Carbon steel support suppression for indication measurements at tube support plate intersections, tube sheet crevice, and free span when associated with deposits.

4.4 Probe Description

A510 M/ULC/HF - .510" diameter Magnetic-Bias high frequency probe designed to detect discontinuities and other tubing variations. They have flexible centering devices for optimum coil centering. These are used for standard bobbin coil examinations.

AX400 6FLC/DIFF - .400" diameter combination Cross-wound/differential coil arrangement for detection of discontinuities at roll transition expansions in tubing that has been sleeved. The differential coil is used for detecting discontinuities in the straight section of the sleeved tubing.

Other probe sizes and variations in coil configurations are acceptable provided they meet the requirements of codes and procedures for the steam generator tubing examination. Prior approval from Florida Power Corporation's ISI Section representative must be obtained.

5.0 Data Analyst Guidelines - Bobbin Examination

5.1 Responsibilities

5.1.1 One individual will be designated as the Senior Analyst. The Senior Analyst is responsible for:

5.1.1.1 Evaluating eddy current data in a manner consistent with the analysis guidelines presented herein.

5.1.1.2 Modifying the analysis guidelines, with concurrence of FPC, to accommodate new or unanticipated circumstances and ensuring that all Lead Analysts and Analysts understand and adapt to the change.

5.1.1.3 The Senior Analyst may assume the role of Lead Analyst and/or Analyst.

5.1.2 Each shift will have a Lead Analyst. The Lead Analyst is responsible for:

5.1.2.1 Evaluating eddy current data in a manner consistent with the analysis guidelines presented herein.

5.1.2.2 Alerting the Senior Analyst to conditions present in the data which are not addressed by the analysis guidelines.

5.1.2.3 Resolving discrepancies identified between primary and secondary analysts.

5.1.2.4 The Lead Analyst may also assume the role of a primary or secondary analyst. He may not resolve his own analysis results if he acted as the primary or secondary analyst.

5.1.3 The Analyst is responsible for:

5.1.3.1 Evaluating eddy current data in a manner consistent with the analysis guidelines presented herein.

5.1.3.2 Alerting the Lead Analyst to conditions present in the data which are not addressed by the analysis guidelines.

5.1.3.3 Acting only as the primary or secondary analyst, not both, for a given reel of data.

5.2 <u>Personnel Qualifications</u>

5.2.1 Personnel analyzing data shall be qualified in accordance with SNT-TC-1A (1975 edition) and certified to Level II or Level III.

5.2.2 In addition, the analyst shall have received specific training in the evaluation of data from non-ferromagnetic tubing and have successfully passed the practical examination specific to Crystal River Unit 3 sceam generators.

5.3 Span and Rotation Settings

5.3.1 Set the 600, 400, and 200 kHz differential channels with the single 100% through wall (TW) hole signal at 40 degrees phase angle plus or minus 3 degrees, starting down and to the right with a span setting that measures 50% of the screen height.

5.3.2 Set the 600, 400 and 200 kHz absolute channels with probe motion or tube inside diameter noise horizontal and the 100% TW hole starting up and to the left with a span setting that measures 25% of the screen height.

5.3.3 Set the 35 kHz differential channel with the broached tube support plate signal horizontal starting left and a span setting that measures 50% of the screen height.

5.3.4 Set the 35 kHz absolute channel with the broached tube support plate signal starting vertically down and a span setting of 50% of the screen height.

5.3.5 Span and rotation alterations may be made as necessary with the approval of FPC for selected channels to accommodate special analysis routines such as tubesheet profilometry.

5.4 Mixes

5.4.1 Mix #1

A 600/200 kHz differential mix shall be established as the primary TSP suppression mix. This mix shall be accomplished by using the broached TSP in the calibration standard. Adjust the phase such that tube noise is horizontal, and the 100% TW hole is starting down and to the right with a span setting that measures 50% of the screen height.

5.4.2 Additional mixes may be included for supplemental Information if desired.

5.5 Normalization

The voltage of all channels shall be normalized in reference to the 600 kHz differential channel. The four (4) 100% throughwall holes shall be set to 6 volts peak to peak off the 600 kHz differential. This shall be saved and stored to all other channels. If the calibration standard doesn't have four (4) 100% throughwall holes, then the four (4) 20% flat bottom holes shall be set to 4 volts peak to peak, saved and stored to all other channels.

Note: Previous voltage normalization was done by setting the broached TSP at 4 volts off the 400kHz channel. Therefore comparison of the voltage from previously called indications should not be made unless the old data is normalized with the new criteria or a correction factor is applied.

5.6 Calibration Curves

5.6.1 Differential Phase Analysis Calibration Curves

Calibration curves shall be set for the 600, 400 and 200 kHz differential and Mix #1. These curves shall be three point phase analysis curves, using the 100, 60 and 20% TW holes. The actual as-built depths for each of the calibration points shall be used. Phase angle measurements should be made with the MAX RATE function.

5.7 Calibration Entries

5.7.1 All calibrations shall be entered to the final report as a Row 999 Tube 999 entry. These entries will be made at the beginning of the calibration group (initial cal.) and at the end of the calibration group (final cal.) and at any interim 4-hr cals as required. Calibration information shall be entered in the appropriate field as shown below:

Row	Col	Volt	Deg	%TW	CH	Location	Extent
999	999	Cal* Time	CAL	Probe Dia.	Cal No.	Cal Message	Analyst ID

Attachment #2 gives some examples of typical calibration entries.
* - Entries shall be military time and right-justified in the field.

The tolerances for calibration checks in which no equipment change or other changes were made to the acquisition set up (4-hour cal checks, for example) are as follows: plus or minus 1 volt, measured off the flaw used for voltage normalization; plus or minus 3 degrees measured off the single 100% TW hole. Calibrations outside these tolerances should be brought to the attention of the Senior or Lead Analyst to determine whether data acquired between cal checks is acceptable. If data is acceptable, a message will be placed in the final cal record (i.e. NO FINAL CAL - DATA ACCEPT).

5.8 Evaluation

5.8.1 All eddy current tube data shall be subject to two separate independent analysis. These are referred to as "primary" and "secondary" analysis.

Note: Secondary analysis is required to report tube degradation conditions only. Section 6.2-6.7 and 7.0 do not apply to secondary analysis.

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

5.8.3 The evaluation shall consist of reviewing lissajous and strip chart displays to the extent that all tube wall degradation and other signals as defined by this document are reported and dispositioned in accordance with the requirements of this document.

5.8.4 Set the lissajous to display the 400 kHz. Set the right strip chart to display the vertical component of the 600/200 kHz differential mix and the left strip chart to display the vertical component of the 200 kHz absolute channel.

5.8.5 Phase angle measurements shall be made utilizing Volts MAX RATE for signals which have a well-defined transition. For cases where no clear transition exists, (i.e., open-loop signals), a Volts peak-to-peak angle shall be used.

The use of guess angle shall be kept to a minimum and only used when the latter two functions do not give a good representation of the indications phase angle.

5.8.6 Any indication shall be evaluated using other available frequencies to ensure that the analysis is correct.

5.8.7 Previous history shall be addressed on all indications.

6.0 Reporting Requirements

6.1 All quantifiable indications of wall degradation ≥ 1% TWD, with a S/N ratio ≥ 5, shall be recorded.

6.1.1 Free span indications shall be reported using the 600 kHz differential channel.

6.1.2 Indications at or within a TSP or Tubesheet shall be reported from the 600/200 kHz differential mix channel.

6.1.3 The location, type of flaw (if possible) and %TWD shall be recorded.

6.2 All indications with a S/N ratio of < 5 shall be recorded as follows:

6.2.1 For indications with a S/N ratio less than 5, only the location and type of flaw (if possible) shall be recorded with an accompanying note of "S/N" in the "%TWD" column.

6.2.2 For all indications which represent possible through-wall degradation, the signal-to-noise ratio (S/N) shall be determined. The method used to determine the signal-to-noise ratio is illustrated in Attachment #5.

6.2.3 The S/N requirements specified may be superseded by the data analyst and the indication assigned a %TWD on a "best-effort basis".

6.3 Dings equal to or greater than 5.0 volts peak to peak or greater shall be reported. This shall be accomplished using the 600 kHz differential channel. All dings occurring at TSP or tubesheet intersections shall be reported using Mix #1.

6.4 Permeability variations equal to or greater than 5.0 volts using the 600 kHz differential channel shall be reported.

6.5 Inside diameter chatter or "ID noise" equal to or greater than 5.0 volts peak-to-peak shall be reported. This will be reported using the 600 kHz differential channel.

6.6 The actual tube extent tested shall be reported as the furthest landmark observed from the entry leg.

6.7 Lower and upper tubesheet "C-type" indications shall be reported. Classification of the indications shall be done by viewing the 400 kHz channel. (See Attachment #3 for a complete listing of codes).

7.0 Graphic Printouts

7.1 Any indication at the 15S TSP, UTS, and the Lane area.

7.2 All wear indications 0-100%.

7.3 Any indications greater than or equal to 20 percent throughwall.

7.4 Any signal assigned a S/N OR "I" code, (i.e. S/N, DSI, DTI) will require graphic printouts.

7.5 The printout shall be of the lissajous from the reporting channel and the secondary graphic shall be of a confirming channel or "D8", if available. The actual printouts shall be established by the Senior Analyst with concurrence from FPC.

8.0 Rerun Codes Obstructed Tubes and Noisy Data

Any tubes requiring rerun for the following reasons shall be recorded as indicated below:

8.1 Supplemental Inspections

8.1.1 All calls occurring at the 15S TSP or upper tubesheet secondary face in the lane or wedge region to be left in service may be examined with a rotating pancake coil (RPC) for supplemental information or disposition.

8.1.2 All wear calls greater than 40% may be further sized and dispositioned using RPC. This will require prior approval by Florida Power Corporation's ISI Section representative.

8.2 Obstructed Tubes

Any tube that is unable to traverse the nominal size probe used for the inspection shall be coded as follows:

8.2.1 Enter the tube number with Rerun Obstructed (ROB) code in the percent column and the area of the obstruction in the "location" column of the report line.

8.2.2 Enter the tube MSG in the percent column and put a message in the "location" field stating the probe size to be used with the subsequent examination. An example of these entries are shown in Attachment #2. This sequence should be followed for all subsequent obstructed examinations of the tube.

8.3 Noisy Data

8.3.1 Undesirable variations are variations in recorded eddy current data that, in the judgement of the Data Analyst, could obscure reportable discontinuities or could cause misinterpretation of flaw depth or location.

8.3.2 Undesirable variations "noise" has been determined by identifying any electrical or noise spikes associated with a faulty probe. This type of noise is readily distinguishable from "tube noise" and will be rejected by the analyst to be reexamined with a new probe. In addition, the 10' sacrificial cable can also induce electrical noise which is easily distinguishable.

8.3.3 If during the data evaluation undesirable variations are noted in the recorded eddy current data, the Data Analysts shall determine what tubes, if any, to be reexamined.

8.3.4 The Data Analyst must continuously verify probe acceptability for each tube examined by reviewing the overall quality of the data and determining if the probe is causing undesirable and interfering signal responses.

9.0 Discrepancy Resolution

9.1 Conditions Requiring Resolution

Prior to any resolution an EDDYNET compare file report shall be generated by comparing the results of the primary and secondary analyses.

9.1.1 If either the primary or secondary analyst or both, reports a flaw indication as greater than or equal to 40 percent throughwall, the LEAD ANALYST shall review the data, resolve the discrepancy or verify the results and document on the Compare File Report (CFR).

9.1.2 If either the primary or secondary analyst reports a S/N or "I" code (such as S/N, DSI, DTI, etc.), the LEAD ANALYST shall review the data and determine the nature of the indication (flaw, no flaw, dent, etc.) and document the results on the CFR.

9.1.3 If either the primary or secondary analyst reports a flaw indication not reported by the other, or if the difference in estimated flaw depth between the two analysts (primary and secondary) exceeds 10 percent, the LEAD ANALYST shall review the data , resolve the discrepancy and document the results on the CFR.

9.1.4 If, during the course of the review, the LEAD ANALYST overrules any defect called, (i.e. changes a repairable indication called by primary or secondary analyst, or both to a nonrepairable call), changes an indication to less than 40% throughwall or to no flaw, then a second LEAD ANALYST is required to review the data and both shall document the results on the CFR.

When concurrence between the two LEAD ANALYSTS cannot be reached, the most conservative resolution of the discrepancy shall be taken, but only with FPC concurrence.

In either case, both LEAD ANALYSTS are required to sign the CFR that documents the final results.

9.1.5 Other discrepancies such as inconsistent extent of test, inconsistent tube identification, etc., shall be resolved by a LEAD ANALYST. See Table 1-1 for a listing of discrepancy conditions.

9.1.6 If either the primary or secondary analyst utilizes the INF code, (i.e. no previously identified =>20% TWD call is observed), the LEAD ANALYST will have to research this tube to determine the reason for not finding the indication. This may involve reviewing previous history and previously recorded data as well as "finger printing" of the tube in question. The reason for not finding the indication will be documented on the CFR.

9.2 Documentation of Resolutions

9.2.1 The LEAD ANALYST shall generate an EDDYNET Compare File Report (CFR) using the latest Version of EDDYNET available. This document will be the comparison report in which the primary and secondary discrepancy will be resolved from.

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9.2.2 The following parameters shall be used:

(a) Voltage Plus or Minus 0.5 volt.
(b) Percent Plus or Minus 10 percent.
(d) Location Plus or Minus 0.5 inch.

All indications equal to or greater than 40 percent throughwall shall be reviewed by the LEAD ANALYST.

9.2.3 The LEAD ANALYST will indicate when the primary or secondary call stands as the final call, if the call is to be changed, if a new call has been made by the LEAD ANALYST or the call is to be deleted on the CFR. If the change required a second LEAD ANALYSTS review it will be indicated by his signature. The first LEAD ANALYST shall be required to sign and date the first page of the CFR and initial all other pages.

9.2.4 All CFR's will be filed on a daily basis and will be the property of FPC upon completion of the examination.

TABLE 1-1

Interpretation Discrepancy Standard

Signals indicative of tube wall degradation shall be resolved if any of the following criteria are met:

* The indication has been recorded by only one analyst.

* The through wall dimension of one of the interpretations is equal to or greater than 40 percent and the other interpretation is less than 40 percent through wall.

* The through wall measurements differ by more than 10 percent.

* The voltage differs greater than plus or minus 0.5 volt.

* The axial location differs by more than .5 inch.

* The through wall dimension is equal to or greater than 40 percent.

* Tube not entered by both analysts.

* Extents tested do not match.

* Mismatching discontinuity characterization codes (WAR vs ODI, DSI vs S/N for example).

* Rerun code vs no rerun code.

* Different probe sizes specified in calibration recorded.

The reported steam generator identifications are not in agreement.

* The reported tape identifications are not in agreement.
* The reported flaw location is beyond the reported extent of test.
* Reported probe entry sides are not in agreement.
* Tubes reported as restricted which do not have a corresponding extent of test.
* Use of three-letter code with no established definition.
* Test extents and flaw elevations do not conform with the number of support members in the steam generator.

10.0 Computer Data Analysis

10.1 Computer Data Screening (CDS) Analysis

10.1.1 Computer Data Screening (CDS) analysis is used as the secondary analysis for bobbin coil data.

10.1.2 The CDS Analyst should establish the Analysis Variables in accordance with Section 5 of this document.

10.1.3 The CR3 CDS Sort Variables are restored from either the hard drive or from disks provided to the CDS Analyst. Attachment 8 provides the sorts which will be used for CDS analysis.

10.1.4 When permanent changes to the sorts are deemed necessary both the Senior Analyst and FPC Representative must concur on the sort changes.

10.2 The CDS Analyst is responsible for:

10.2.1 Evaluating ECT Data in a manner consistent with the guidelines presented herein.

10.2.2 Operation of the CDS system, review and editing of the CDS final report to eliminate double entries, false calls and to ensure complete analysis of all tubes. This may include manual analysis of certain tubes that CDS could not screen for various reasons.

10.2.3 Alerting the Lead Analyst to conditions present in the data which are not addressed by the analystguidelines or current CDS sorting parameters.

10.3 CDS Setup

10.3.1 The following configurations will be used for CDS (secondary) analysis. This setup is in addition to or replaces the normal configuration.

10.3.1.1 Mix P4 - 600/200 cc (cross correlation filter) differential. Set the cc filter to five. Suppress the carbon steel broached support ring.

10.3.1.2 Channel 8 - 35 kHz Absolute - Set phase at approximately 60 degrees using the 100% through-wall hole with the initial trace going up. Support plates in the steam generator should then be horizontal.

11.0 Sleeve Examinations

11.1 Examinations Frequencies

A sixteen channel configuration will be used with the following frequencies:

400 kHz Differential Standard Bobbin Coil - This is the inspection frequency to examine the free span section of the sleeve and a TSP suppression mix channel.

400 kHz Absolute Standard Bobbin Coil - This is a defect confirmation channel.

400 kHz Differential Crosswound Coil Sets #1 & #2 - This is a defect confirmation channel for use in rolls and roll transitions. And the parent tubing adjacent to the sleeve end. May be also used with a three channel mix.

250 kHz Differential Standard Bobbin Coil - This is a defect confirmation channel.

250 kHz Absolute Standard Bobbin Coil - This is a defect confirmation channel.

250 kHz Differential Crosswound Coil Sets #1 & #2 - This is a defect confirmation channel and may be used with a three channel mix.

150 kHz Differential Standard Bobbin Coil - This is a defect confirmation channel and a TSP suppression mix.

150 kHz Absolute Standard Bobbin Coil - This is a defect confirmation channel.

150 kHz Differential Crosswound Coil Sets #1 & #2 - This is defect confirmation channel and a roll transition suppression mix channel. May also be used with a three channel mix.

75 kHz Differential Standard Bobbin Coil - This is a defect confirmation channel and a TSP suppression mix channel.

75 kHz Absolute Standard Bobbin Coil - This is a defect confirmation channel.

75 kHz Differential Crosswound Coil Sets #1 & #2 - This is a defect confirmation channel and a roll transition suppression mix channel. May also be used with a three channel mix.

11.2 Sleeve Characteristics

The OTSG sleeves are made of Inconel 600 or Inconel 690, .525" OD. and .050" wall thickness. The sleeves are rolled in place with approximately 1.5" long rolls. These sleeves are 80" or 31" long, installed at the upper tubesheet with one roll at the upper tubesheet primary face and two rolls near the lower sleeve end.

11.3 Crosswound Examination

11.3.1 Area of Interest

The crosswound areas of interest include the rolls, roll transitions and the parent tubing adjacent to the sleeve end.

11.3.2 Span and Rotation Settings

Since the amplitudes of the flat bottom holes are related to their position relative to each crosswound coil set, the calibration standard should be rotated approximately 90 degrees between each calibration pull. The analyst should first identify which record of the calibration pull set delivers the highest sensitivity to the calibration flaws for each coil set, then use that pull for calibration.

Set all channels with the 100% TW sleeve flaw at 40 degrees plus or minus 5 degrees; with the phase rotation starting down and to the right, measuring full vertical screen height.

Note: Since the coils are crosswound, any subsequent calibration pull or any other flaw may start down to the right or up to the left (180 degrees phase shift) depending on the flaw location in relation to the crosswound coil set.

A typical sleeve calibration standard is shown in Attachment #4.

11.3.3 Mixes

A 150/75 kHz roll expansion mix shall be made for each coil set (2 mixes total). For each mix a clean roll transition in the calibration standard shall be suppressed. Set the 100% TW sleeve flaw at approximately 40 degrees starting down and to the right at a span setting of 50% of screen height. After mixing, ensure that each mix has sufficient sensitivity to detect the 40% TW sleeve and parent tube roll transition flaws (I and J in the Attachment #4), and that the 40% TW parent tube flaw is detectable at the sleeve end (flaw K in Attachment #4). If the sleeve end flaw is not discernible from a nonflawed sleeve end, a separate mix for sleeve end suppression shall be made for each coil set. If no unflawed sleeve end exists in the calibration standard, a steam generator - installed sleeve end signal may be used. In this case the tube number containing the sleeve shall be recorded in the analyst final report.

Other mixes, including three channel mixes (turbo), may be used in addition to those listed above for the purpose of obtaining additional information or optimizing the sleeve examination.

11.3.4 Voltage Normalization

The voltage of all channels shall be normalized in reference to the 250 kHz channel, separately for each coil set. The 100% TW sleeve flaw shall be set to 5 volts and all other channels saved and stored.

11.3.5 Strip Charts

The vertical component of either a basic channel or a mix for each coil set shall be monitored on the two long strip charts.

11.3.6 Calibration Curves

No calibration curves are necessary for crosswound analysis.

11.3.7 Data Entries to Final Report

The phase and amplitude of any indication detected shall be compared to the calibration standard flaws and if the signal appears to represent a flaw, then the indication detected shall be entered as 40% TW in the final report.

For each indication reported, "TUB" or "SLV" shall be entered in the comments field of the final report indicating the material containing the signal. Example of crosswound data entries are given below.

Row	Col	Volt	Deg	%TW	CH	Location			Extent
76	2	1.90	90	40	M2	UTE	-1.30	SLV	14th TSP
77	6	3.01	78	40	M1	15S	TSP-5.00	SLV	14th TSP

11.3.8 Reporting Criteria

The following conditions shall be reported, as a minimum:

All indications of sleeve or parent tube wall loss, regardless of depth.

Any obstruction in the sleeve or parent tubing.

11.4 Sleeve Bobbin Coil Examination

11.4.1 Area of Interest

The bobbin coil areas of interest are the sleeve and parent tubing in the freespan (unrolled) portion of the sleeve.

11.4.2 Span and Rotation Settings

Set all differential channels with the 100% TW sleeve flaw at 40 degrees plus or minus 5 degrees, with phase rotation starting down and to the right, setting amplitude 50% full vertical screen height.

Set all absolute channels with the 100% TW sleeve flaw at 40 degrees plus or minus 5 degrees, with phase rotation starting up and to the left and setting amplitude to 25% full vertical screen height.

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11.4.3 Mixes

A 400/150 kHz differential mix shall be established for the TSP suppression. This mix shall be accomplished by using the broached TSP in the calibration standard. Set the 100% TW sleeve flaw at 40 degrees plus or minus 5 degrees, with phase rotation starting down and to the right, setting the amplitude to 50% full vertical screen height.

Additional mixes, including three channel mixes (turbo), may be used to obtain additional information or optimize the sleeve examination.

11.4.4 Voltage Normalization

The voltage of all channels shall be normalized in reference to the 400 kHz differential channel. The broached TSP in the calibration standard shall be set to 4 volts peak-to-peak, save and store to all other bobbin coil channels.

11.4.5 Strip Charts

The charts use for the crosswound coils will be used unless a standard coil probes is being used. In the case of case of standard bobbin, one differential and one absolute channel with be displayed on the long strip charts.

11.4.6 Calibration Curves

Calibration curves shall be set for the 400 kHz differential channel and any other channel used to record a throughwall indication. A three point degree calibration curve shall be set using the 100, 60 and 20% TW sleeve holes, using the as-built depths for the actual calibration values. An additional parent tubing 3 point phase angle calibration curve shall be made for any indication detected in the parent tubing.

11.4.7 Data Entries

Sleeve examination data entries shall be identical to the tubing examination data entries, with the exception that "TUB or "SLV" shall be entered in the comments field of the final report for any throughwall indications detected in the parent tubing or sleeve.

11.4.8 Reporting Criteria

The following conditions shall be reported, as a minimum:

All indications of sleeve or parent tube wall-loss, regardless of depth.

Any obstruction in the sleeve or parent tubing.

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RPC GUIDELINES
APPENDIX A

TABLE OF CONTENTS

B&W NUCLEAR TECHNOLOGIES
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1.0 AREA OF INTEREST

The area of interest for all RPC examinations is the full extent of collected data. For rolled plugs, special emphasis will be on the full rolled area from the toe to the heel. The toe and the heel are two transitions of the rolled areas (See Attachment #6). The roll is approximately 1.25 inches long and is located approximately .5 inch from the plug end. Due to roller movement, or re-rolling, the roll length may be greater than 1.25 inches, and may extend to the plug end.

2.0 ANALYSIS SET-UP

The inspection frequencies shall be identified by B&W Nuclear Technologies Level III Eddy Current prior to inspection start up. These frequencies are normally 300kHz, 200kHz, 100kHz, and 10kHz operating in the absolute mode. The 300 kHz absolute channel shall be viewed as the primary reference frequency.

When a TSP is required for analysis set-up, the drilled TSP in the calibration standard shall be used. If no TSP exists in the calibration standard, then the signal to be used for mix suppression shall be determined by the lead analyst (B&W Nuclear Technologies). The TSP and the tube number used in this instance shall be recorded in the final report.

2.1 Span and Rotation Settings

Set the 300, 200, and 100 kHz absolute channels so that probe motion is horizontal and the initial trace movement of the 100% through-wall flaw is up, with the span set so that the smallest detectable calibration flaw is clearly visible on the screen.

Set the rotation of the trigger channel so that the signal is going up and the small leg is horizontal. Adjust the span to 4 divisions.

2.2 Mix

A 300/100 kHz mix shall be established on process channel P1 as the primary TSP suppression mix. This mix shall be accomplished by using the drilled TSP in the calibration standard. Set the rotation so that probe motion is horizontal and the initial trace movement of the 100% TW flaw is up. Set the span so that the smallest detectable calibration flaw is clearly visible on the screen. Other mixes may be set-up at the analyst's discretion.

2.3 Filter

A filter shall be established on process channel P2. The primary reference frequency pancake coil shall have applied a Band Pass filter with the following values:

1. Sharpness - 23
2. Low Cut - 10
3. High Cut - 100

2.4 Normalization

Using the 300 Khz channel, set the voltage using the 100% TW axial EDM notch in the calibration standard to ten (10) volts peak-to-peak and save and store this value to all other channels.

2.5 Calibration Curves

Wear shall be sized with the TSP mix using a 3 point voltage curve. These will be set up on a wear calibration standard using the as-built depth values. Other voltage or phase curves may be set up at the analyst's discretion.

No calibration curves are required for plug examination.

VERT-MAX shall be used for the calibration and measurement o f wear indications.

2.6 Strip Charts

For tube analysis, set the left strip chart to display the vertical component of Filter P2. Set the right strip chart to display the vertical component of the 10 kHz channel. The analyst may adjust the strip charts at their discretion.

For plug analysis, set one strip chart to display the vertical component of the primary channel. The other chart may be set at the analyst's discretion.

2.7 Calibration Entries to Disk

All calibrations shall be entered to the final report as a Row 999, Col 999 entry. Calibration information shall be entered in the appropriate field as shown below:

ROW	COL	VOLTS	DEG	%TW	CH	LOCATION	EXTENT
999	999	Cal	Cal	Probe	Tape	Cal	Analyst
	Time		Dia.	No.	Message		

Attachment #2 gives some examples of typical calibration entries.

3.0 PLUG ANALYSIS

3.1 Rolled Plugs

It is very important that the full extent of the plug be examined. For rolled plugs, this includes the entire rolled area out to the open end of the plug. Attachment #6 displays a complete examination of a plug. A smooth transition leading to the plug end (probe in air) signal must be seen. This verifies that the probe did not jerk out of the plug with the resultant loss of examination coverage near the plug end.

4.0 REPORTING CRITERIA

4.1 All indications of tube wall degradation shall be reported. For plug analysis, all permeability indications shall be reported.

4.2 Indications in the freespan area of the tubing shall be recorded with the 300 kHz absolute channel whenever practical.

4.3 Indications occurring within tube supports shall be recorded using the 300 Khz channel whenever practical.

4.4 Indications occurring at tube support edges or otherwise interfered with may be reported with the 300/100 kHz mix channel.

4.5 All indications of tube wall degradation shall be reported with a characterization code in the percent column. The characterization codes to be used for reporting flaw indications are SAI, MAI, SCI, MCI and VOL and are defined as follows:

SAI, MAI - Single and Multiple axially oriented crack-like indications. Typically showing an enhanced response on the circumferentially-wound coil.

SCI, MCI - Single and Multiple circumferentially oriented crack-like indications. Typically showing an enhanced response on the axially-wound coil.

VOL - Volumetric indication typically showing nearly equivalent response on each of the coil configurations.

Wear indications shall be reported with the measured depth, in the %TW column, as determined from the wear curve set up.

4.6 Signal correlation should be determined through evaluation of the phase relationship noted among examination frequencies. Indication characterization should be determined through evaluation of signal amplitude and geometric relationships noted among the various coil configurations.

5.0 INDICATION LENGTH AND WIDTH MEASUREMENTS

5.1 RPC Clip Plot Measurements

RPC clip plot measurements will be performed on all bobbin coil S/N indications examined.

5.1.1. The primary frequency of 300 kHz absolute will be used to size the axial and circumferential extents of the indications.

5.1.2 The setup and calibration requirements for reporting indications are the same as those in Section 2.0.

5.2 Clip Plot Setup and Calibration Requirements

5.2.1 After performing the basic setup select the "MRPC/CRKMAP" menu. Go to user select and set the tubing diameter to .551".

5.2.2 Set the axial scale in reference to the EDM calibration standard. Refer to the EDM calibration standard drawing for the standards total length.

5.2.3 Select "MEASFLAW". Plot the 60% O.D. EDM notch at 270. Position the threshold cursor just above tube noise.

5.2.4 Select "CLIP PLOT" function and plot the data at 0 degrees. "BOX ANGLE" must be kept at 0 degrees.

5.2.5 Perform length and width measurements by drawing the box equivalent to the same size of the 60% OD EDM notch signal. After the measurement is performed, move the box just below the signal.

5.2.6 Verify that the total length and width measurement is equivalent or greater than the as-built length and width of the 60% OD EDM notch. If the measurement is undersized reset the axial scale.

5.2.7 When plotting the data, set axial scale to .86" +/- .20".

5.3 Reporting Clip Plot Measurements

5.3.1 Select the "REPORT ENTRY" menu and enter the length and width measurement to the final report. See Attachment 10 for the final report entry.

5.3.2 Two graphics are required for the clip plot measurements. The first graphic will display the normal CSCAN plot and the second graphic will display the clip plot. This will be performed for each individual indication as well as clustered indications. Appendix 1 of the analyst station reference book provides examples of the required graphics for the normal CSCAN and clip plot measurements.

6.0 RECORDING CRITERIA

6.1 Axial Locations

All measurements shall be made using the following criteria:

* An indication location shall be measured from the center of TSP or a tubesheet edge to the center of the indication being reported.

* Axial indications shall be measured from indication edge-to-edge (for example: LTSF +12.10 TO 14.60).

* Set the axial scale based on known locations in the steam generator or use calibration standard defects with distances documented on as-built drawings.

* Positive direction is physically upwards in the generator (i.e., 1st TSP + 1.00 inches is 1 inch above the 1st TSP).

* Measurements may be made in either the positive or negative direction using the nearest available landmark.

* Wear at TSP's shall always be recorded as "location + 0.00".

* Plug indications shall always be located from the tube end (UTPF or LTPF) depending on plug location. Extent will be top of tubesheet (UTSF or LTSF) depending on location of plug.

6.2 Discontinuity Characterization Codes

Three digit codes used to further characterize the discontinuity type (WAR, etc.) shall be entered in the last 3 spaces of the location field in the final report. These types of codes can be found in Attachment #4.

6.3 Wall-Loss Indications

6.3.1 Freespan Indications

All calls in the freespan area of the tubing shall be recorded with the primary frequency.

6.3.2 TSP Indications

TSP indications can be called with a mix or primary frequencies, whichever gives the best representation.

6.3.3 Plug Indications

All indications in plugs shall be recorded. Plugs shall be analyzed using the primary frequency.

6.4 Obstructed Tubes

Obstructed tubes shall be reported as in section 8.0 of the bobbin guidelines.

6.5 Graphics Printouts

The primary analyst shall be responsible for printing graphics. Pictures shall be made for all degradation calls.

6.5.1 MRPC

For each flaw, four (4) graphics are required.

The first picture shall be of the X-Y lissajous with phase, amplitude and field code edited in the "%TW" column. For the second picture, a terrain plot shall be generated using the same data channel as in picture 1. The third picture will be a terrain plot of the axial coil. The fourth picture will be a terrain plot of the circumferential coil.

7.0 DATA COMPARISON

7.1 Responsibilities

The primary analyst shall generate the data to be used in the final report. This analyst is responsible for recording all indications reportable by the analysis procedure.

The secondary analyst shall generate the comparison data. This analyst is responsible for recording all tube wall indications reportable by the analysis procedure.

7.2 Data Discrepancies

The basis for the data comparison shall be the Interpretation Discrepancy Standard identified in paragraph 6.3. All identified differences in data interpretation shall be reviewed by the Senior or Lead analyst to arrive at the final interpretation.

The optical disk containing both the primary and secondary analysis is loaded into the resolution program for comparison. A record of all primary and secondary data, and any changes to those results through the resolution process is maintained on the optical disk.

7.3 Interpretation Discrepancy Standard

Signals indicative of tube wall degradation wear shall be resolved if any of the following criteria are met:

* The indication has been recorded by only one analyst.
* The through-wall dimension of one of the interpretations is equal to or greater than 40%, and the other interpretation is less than 40%.

- * The through-wall dimension of one of the interpretations is equal to or greater than 20%, and the other interpretation is less than 20%.
- * The through-wall measurements differ by more than 10%.
- * The voltage differs by more than 1 volt.
- * The axial location differs by more than 1 inch.

Any of the following conditions are also subject to resolution:

- * Tube not entered by both analysts.
- * Extents tested do not match.
- * Mismatching discontinuity characterization codes (WAR vs. ODI, for example).
- * Rerun code vs. no rerun code.
- * Different inspection legs specified.

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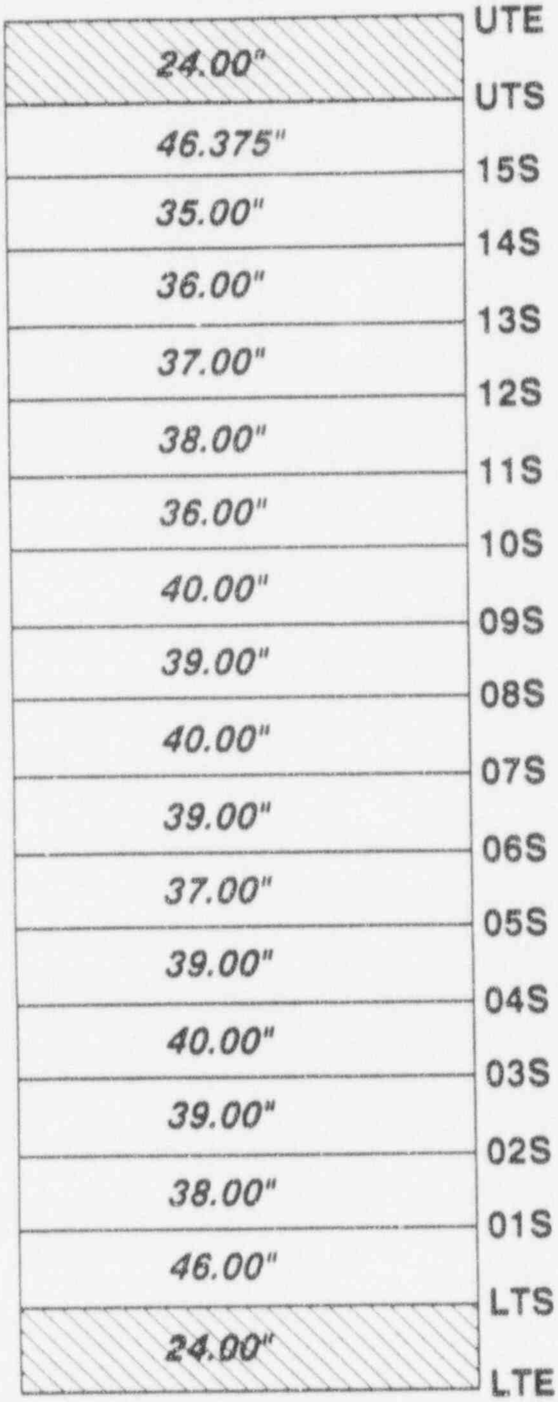
ATTACHMENT #1

OTSG ELEVATION MAP



***** TUBE DATA *****

NO. OF TUBES = 15531

MATERIAL = INCONEL 600

NOMINAL DIA. = 0.625"

NOMINAL WALL = 0.034"

TUBE LENGTH = 673.375"

***** SUPPORT DATA *****

HOLE TYPES = DRILLED & BROACHED

MATERIAL = CARBON STEEL

THICKNESS = 1.50"

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ATTACHMENT #2

FORMAT FOR ENTERING CAL RECORDS AND OTHER DATA

			CAL TIME	"CAL"	PROBE SIZE	CAL NO.	"INITIAL (OR FINAL) CAL"	ANALYST CODE
SG	ROW	COL	VOLTS	DEG	%TW	CH#	LOCATION	EXTENT
A	999	999	1610	CAL	510	015	INITIAL CAL	X1234
A	33	104			MSG		SEE CAL 61	
A	24	92						UTELTE
A	46	55	1.01	150	18	M 1	15S + 0.00 WAR	UTELTE
A	77	5	2.61	101	45	M 1	UTS + 0.00 MBM	UTELTE
A	77	5			RPC		UTS + 0.00	UTELTE
A	999	999	1825	CAL	510	015	CAL OUT - OLD PROBE	X1234
A	999	999	1908	CAL	510	015	NEW PROBE CAL	X1234
A	41	42	1.14	97	34	1	02S + 18.87 TO31.8 AXI	UTELTE
A	66	3			ROB		02S + 18.00	03S
A	66	3			MSG		RERUN WITH .480 PROBE	03S
A	999	999	1929	CAL	510	015	FINAL CAL	X1234
A	888	888		CAL			NO FINAL CAL - DATA OK	X1234
A	888	888		CAL			NO FINAL CAL - PROBE DIED	X1234

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ATTACHMENT #3

#	CODE	DESCRIPTION
1.	ODI	OUTER DIAMETER (GENERAL)
2.	IDI	INNER DIAMETER (GENERAL)
3.	AXI	AXIAL INDICATION
4.	CCL	CIRCUMFERENTIAL (CRACK LIKE)
5.	WAR	WEAR
6.	PIT	PITTING
7.	ADS	ABSOLUTE DRIFT SIGNAL
8.	BLG	BULGE
9.	DNT	DENT
10.	DNG	DING
11.	DSI	DISTORTED SUPPORT IND
12.	ICR	INCOMPLETE ROLL
13.	MBM	MANUF. BUFF MARK
14.	DTI	DISTORTED TSH IND
15.	DSS	DISTORTED SUPPORT SIGNAL
16.	IRR	IRREGULAR ROLL
17.	DTS	DISTORTED TSH SIGNAL
18.	NQI	NON-QUANTIFIABLE IND
19.	NQS	NON-QUANTIFIABLE SIGNAL
20.	NEX	NO EXPANSION
21.	CHT	CHATTER
22.	COP	COPPER DEPOSIT
23.	CSP	CRACKED SUPPORT PLATE
24.	DST	DISTORTED SIGNAL
25.	GMD	GEOMETRIC DISTORTION
26.	LC1	LTS C1 INDICATION
27.	LC2	LTS C2 INDICATION
28.	LCB	LTS C3 (BANANA)
29.	LPS	LOOPS
30.	NDD	NO DETECTABLE DEGRADATION
31.	OBS	OBSTRUCTED
32.	PRM	PERMEABILITY VARIATION
33.	MAI	MULTIPLE AXIAL IND
34.	MCI	MULTIPLE CIRCUMFERENTIAL IND
35.	SAI	SINGLE AXIAL IND
36.	SCI	SINGLE CIRCUMFERENTIAL IND
37.	S/N	SIGNAL-TO-NOISE
38.	SLG	SLUDGE DEPTH
39.	MSG	ANALYST MESSAGE
40.	UC1	UTS C1 INDICATION
41.	UC2	UTS C2 INDICATION
42.	UC3	UTS C3 INDICATION
43.	UDS	UNDEFINED SIGNAL
44.	PID	POSITIVE IDENTIFICATION
45.	PLP	POSSIBLE LOOSE PART
46.	PVN	PERMEABILITY VARIATION
47.	IDC	ID CHATTER
48.	INF	INDICATION NOT FOUND
49.	INR	INDICATION NOT REPORTABLE
50.	VOL	VOLUMETRIC - 3CRPC
51.	RBD	RETEST - BAD DATA
52.	RFX	RETEST - FIXTURE
53.	RIC	RETEST - INCOMPLETE
54.	RCL	RETEST - CLARIFICATION
55.	RNF	RETEST - INDICATION NOT FOUND
56.	ROB	RETEST - OBSTRUCTED
57.	RPI	RETEST - POSITIVE ID
58.	RNT	RETEST - TUBE NOT RUN
59.	RNC	RETEST - TUBE NUMBER CHECK
60.	RTR	RETEST - RESTRICTED
61.	RPC	RETEST - RPC EXAM REQUESTED

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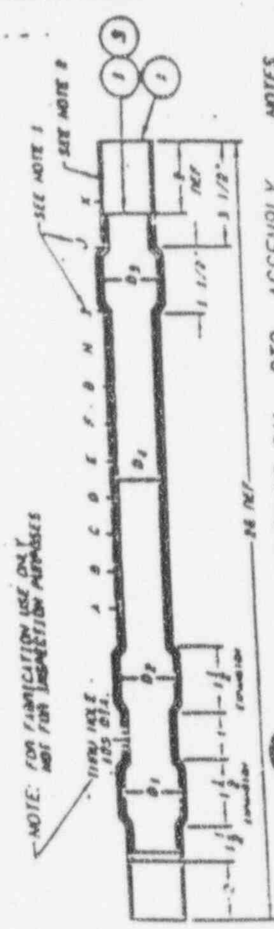
ATTACHMENT #4

B&W NUCLEAR SERVICE COMPANY

REVISIONS



(1) OTSG SLEEVE/TUBE CAL. STD. ASSEMBLY

NOTES.
1. FLAWS I AND J CENTERED IN TRANSITION AREA.
2. VIBRA ETCH DRAWING NO. IN THIS AREA 1/8 HIGH LETTERS FOR "AS BUILT" STANDARD. 12041458.
3. THIS CAL STD BUILT TO DESIGN DRAWING 1186082C-2.

PROPRIETARY

	AS BUILT DIM
D_1 I.D.	.4710
D_2 I.D.	.4936
D_3 I.D.	.4641
D_4 I.D.	.4315

FLAT BOTTOM HOLE	A	B	C	D	E	F	G	H	I	J	K
DIAMETER	.1860	.1860	.1100	.0510	.1870	.1870	.1100	.0510	.1870	.1870	.1870
DEPTH	.0070	.0145	.0220	THRU	.0090	.0190	.0260	THRU	.0190	.0140	.0140
% THRU WALL ACTUAL	20	43	65	100	20	42	58	100	48	41	41

BWNS PROPRIETARY

FILENAME: OTSG145
DISK NO. 164-88

OTSG SLEEVE/TUBE CALIBRATION STANDARD AS-BUILT

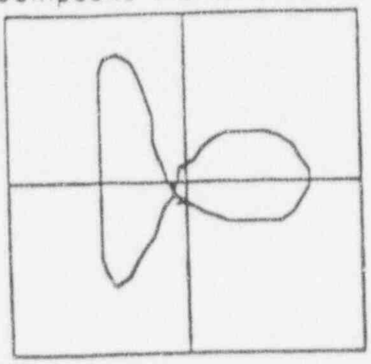
ATTACHMENT #5

$$S/N = \frac{Vs}{Vr}$$

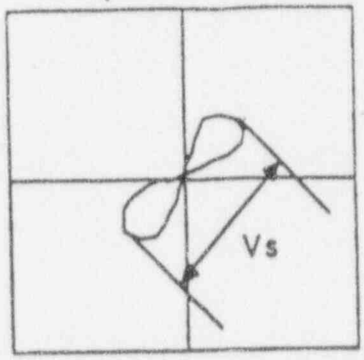
Vs = Signal Voltage
Vr = Noise/Residual Voltage

Determining S/N Ratio Using Multiparameter or Computerized Analysis

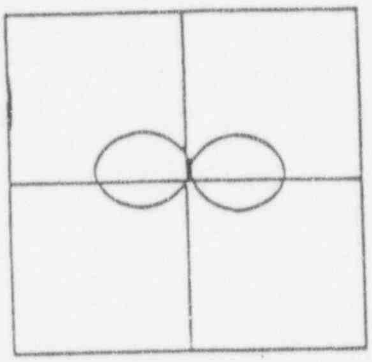
Composite Indication & TSP



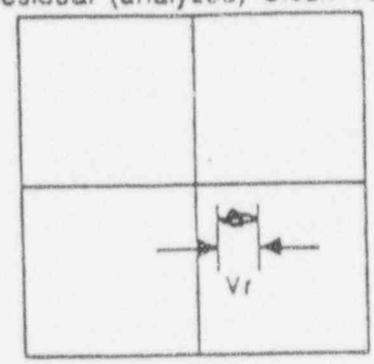
Analyzed Indication



Clean TSP

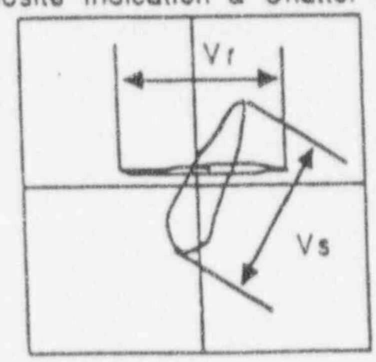


Residual (analyzed) Clean TSP



Determining S/N Ratio Using a Single Frequency Technique

Composite Indication & Chatter Noise



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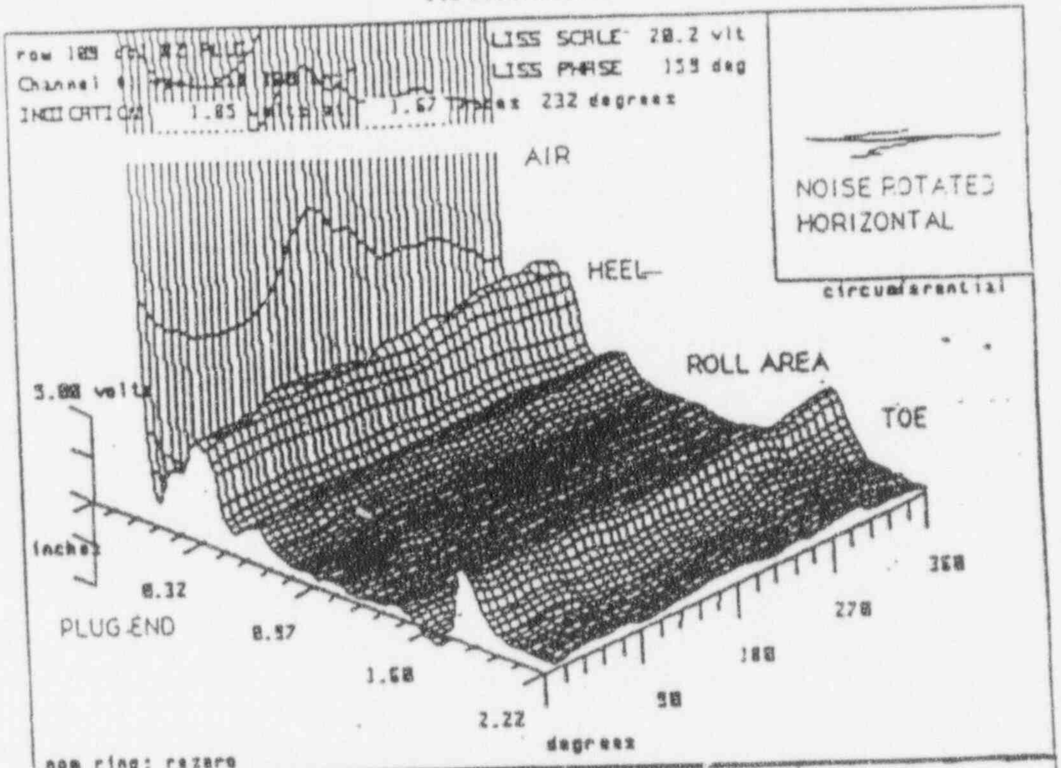
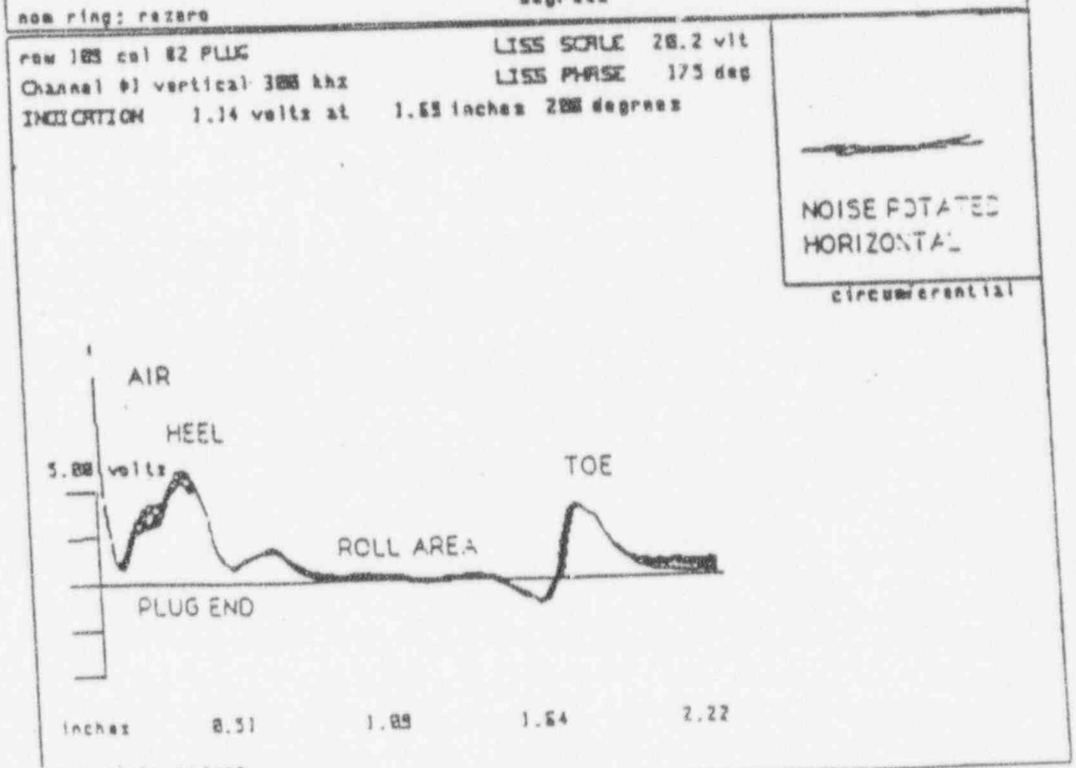
ATTACHMENT #6





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ATTACHMENT #7

```
tube_sheet_lower
 Chan=20     d_peaks Win=  1      volts >0.60 <1000.00
 Chan=17  t_amp_vpp Win=120      volts >0.60 <200.00 r
 Chan=17    t_amp_mr Win=120      angle >30 <170 r
 Chan=17    max_rate Win= 20      flaw >1 <100 r
 Chan=17    t_amp_mr Win=120      [19] angle >35 <160
 Chan=17    t_amp_mr Win=120      [3] angle >35 <150
 Chan= 8   anywhere Win=120      loc >TOP SAMP +1.00 <BTM SAMP +1.00
 Chan=17    t_amp_mr Win=120      [5] angle >35 <150
tube_supports
 Chan=20     d_peaks Win=  1      volts >0.75 <1000.00
 Chan=17    t_amp_mr Win=120      volts >0.75 <200.00 r
 Chan=17    t_amp_mr Win=120      angle >30 <170 r
 Chan=17    t_amp_mr Win=120      [3] angle >35 <160
 Chan= 8   anywhere Win=120      loc >TANG-HL -36.00 <TOP SAMP +36.00
 Chan=17    t_amp_mr Win=120      [19] angle >35 <160
 Chan= 8    vert_max Win= 40      volts >10.00 <1000.00
free-span
 Chan=20     d_peaks Win=  1      volts >0.40 <1000.00
 Chan= 1    t_amp_mr Win=120      volts >0.40 <200.00 r
 Chan= 1    t_amp_mr Win=120      angle >35 <170 r
 Chan= 1    t_amp_mr Win=120      [3] angle >35 <140
 Chan= 8   anywhere Win=120      loc >TANG-HL +1.00 <TOP SAMP -1.00
 Chan= 1    t_amp_mr Win=120      [5] angle >35 <115
 Chan= 8    vert_max Win= 40      volts >0.00 <10.00
tube_sheet_upper
 Chan=20     d_peaks Win=  5      volts >0.60 <1000.00
 Chan=17    t_amp_mr Win=120      volts >0.60 <200.00 r
 Chan=17    t_amp_mr Win=120      angle >30 <170 r
 Chan=17    max_rate Win= 20      flaw >1 <100 r
 Chan=17    max_rate Win=120      [19] angle >35 <160
 Chan=17    t_amp_mr Win=120      [3] angle >35 <150
 Chan= 8   anywhere Win=120      loc >AV1 -1.00 <TANG-HL -1.00
 Chan=17    t_amp_mr Win=120      [5] angle >35 <150
```

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ATTACHMENT #8

APPENDIX H

SIGNAL TO NOISE RATIO SIGNIFICANCE

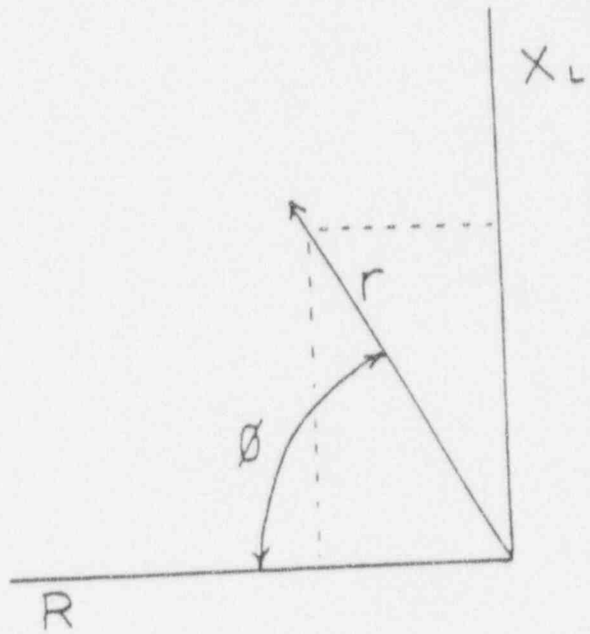
SIGNAL TO NOISE RATIO DISCUSSION

The eddy current defect signal is directly related to the probe coil's total opposition to current flow or impedance (Z). The impedance of the circuit is determined by the inductive reactance (X_L) and the coil's resistance (R). Figure one illustrates this relationship and how vector mechanics is used to determine the phase angle of a defect signal. The phase angle of a bobbin coil eddy current signal has traditionally been used to estimate the percent through wall penetration of the defect. Typical calibration standards correlate a 100% through wall indication to a 40° phase angle. A 40% through wall indication is typically correlated to a 130° phase angle for a 600 kHz inspection frequency.

Signal to noise ratio is the ratio of the magnitude of the signal of interest(defect signal) to the magnitude of any undesirable extraneous signal which occurs simultaneously. The attached figure 2 provides a vector mechanics illustration of how the vector produced by noise interferes with the defect signal vector and can cause an increase in the error angle with respect to the resultant signal.

Figure 3 provides a correlation between error angle as a result of noise and the defect signal to noise ratio. As shown on figure 3, establishing a 5:1 minimum ratio as the cutoff at which above phase angle calls are made based on eddy current signals ensures that the error angle affecting the defect signal is below 10° such that error in estimation of percent through wall is less than 10%.

VECTOR MECHANICS ILLUSTRATION OF HOW A PHASE ANGLE IS DETERMINED FOR A DEFECT SIGNAL



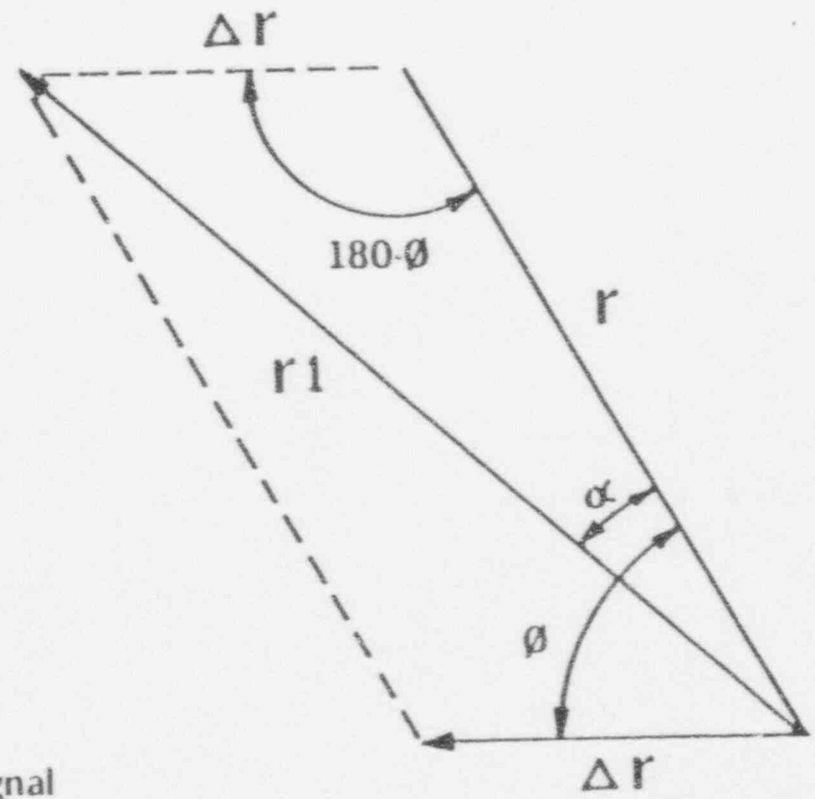
r = Defect Signal (Impedance (Z))
X_L = Inductive Reactance
R = Resistance
Ø = Phase Angle

$$r = X_L^2 + R^2$$

$$Ø = \tan^{-1} (X_L/R)$$

FIGURE 1

Vector Mechanics Illustration of How Noise Signal Vector (Δr) Interferes with Defect Signal Vector (r) Producing Resultant Signal (r1)



r = Original defect signal

Δr = Noise signal

Ø = Angle between defect signal and noise signal

α = Change in phase (Error angle)

r1 = Resultant signal

Error Angle vs Signal to Noise Ratio for Different Values of Ø