CONNECTICUT YANKEE ATOMIC POWER COMPANY

BERLIN, CONNECTICUT
P.O. BOX 270 HARTFORD, CONNECTICUT 06141-0270

TELEPHONE
203-665-5000

March 24, 1988
Docket No. 50-213
A07040
Re: Bulletin 88-02

Mr. William T. Russell, Regional Adm ıistrator
Region I
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, Pennsylvania 19406

Gentlemen:

Haddam Neck Plant
Response to NRC Bulletin No. 88-02

NRC Bulletin No. 88-02[1] requires licensees to take actions to minimize the potential for a steam generator tube rupture event caused by a rapidly propagating fatigue crack such as occurred at North Anna Unit 1 on July 15, 1987. This is applicable only to plants with certain models of Westinghouse steam generators. As such, the Haddam Neck Plant is the only Northeast Utilities operated unit for which this issue is a concern. The actions taken and the results achieved are hereby provided:

(1) NRC Bulletin No. 88-02, "Rapidly Propagating Fatigue Cracks in Steam Generator Tubes", dated February 5, 1988.

IE11
1/1

Item A:

The most recent steam generator inspection data should be reviewed for evidence of denting at the uppermost tube support plate. Inspection records may be considered adequate for this purpose if at least 3% of the total steam generator tube population was inspected at the uppermost support plate elevation during the last 40 calendar months. "Denting" should be considered to include evidence of upper support plate corrosion and the presence of magnetite in the tube-to-support plate crevices, regardless of whether there is detectable distortion of the tubes. The results of this review shall be included as part of the 45-day report. Where inspection records are not adequate for this purpose, inspections of at least 3% of the total steam generator tube population at the uppermost support plate elevation should be performed at the next refueling outage. The schedule of these inspections shall be included as part of the 45-day report and the results of the inspections shall be submitted within 45 days of their completion. Pending completion of these inspections, an enhanced primary-to-secondary leak rate monitoring program should be implemented in accordance with paragraph C.1. below.

Response A:

Steam Generator Eddy Current Testing (ECT) data for 1987 has been reviewed for evidence of denting at the uppermost tube support plate. A 100% inspection was performed at that time and a number of tubes were determined to be so dented. Information regarding numbers, distribution, and analysis technique is provided in Attachment 1.

Item B:

For plants where no denting is found at the uppermost support plate, the results of future steam generator tube inspections should be reviewed for evidence of denting at the uppermost support plate. If denting is found in the future, the provisions of item C below should be implemented. Commitments to implement these actions shall be submitted when the results of A above are submitted.

Response B:

Since denting has been found, this is not applicable.

Item C.1:

Pending completion of the NRC staff review and approval of the program described in C.2 below or completion of inspections specified in item A above to confirm that denting does not exist, an enhanced primary-to-secondary leak rate monitoring program should be implemented as an interim compensatory measure within 45 days of the date of receipt of this bulletin. Implementation of this program shall be documented as part of the 45-day report. The enhanced monitoring program is intended to ensure that if a rapidly propagating fatigue crack occurs under flow-induced vibration, the plant power level would be reduced to 50% power or less at least 5 hours before a tube rupture was predicted to occur. The effectiveness of this program should be evaluated against the assumed time-dependent leakage curve given in Figure 1.

This program should consider and provide the necessary leakage measurement and trending methods, time intervals between measurements, alarms and alarm setpoints, intermediate actions based on leak rates or receipt of alarms, administrative limits for commencing plant shutdown, and time limitations for (1) reducing power to less than 50% and (2) shutting down to cold shutdown. Appropriate allowances for instrument errors should be considered. Finally, the program should make provision for out of service radiation monitors, including action statements and compensatory measures.

Response C.1:

A monitoring program exists at the Haddam Neck Plant and is administratively controlled. Highlights of these procedures and an evaluation of their effectiveness are included in Attachment 2. This program meets the criteria of reducing power to 50% or less at least 5 hours before tube rupture.

Item C.2:

A program should be implemented to minimize the probability of a rapidly propagating fatigue failure such as occurred at North Anna Unit 1. The need for long-term corrective actions (e.g., preventive plugging and stabilization of potentially susceptible tubes, hardware, and/or operational changes to reduce stability ratios) and/or long-term compensatory measures (e.g., enhanced leak rate monitoring program) should be assessed and implemented as necessary. An appropriate program would include detailed analyses, as described in subparagraphs (a) and (b) below, to assess the potential for such a failure. Alternative approaches and/or compensatory measures implemented in lieu of the actions in subparagraphs (a) or (b) below should be justified.

Although the 45-day report shall provide a clear indication of actions proposed by licensees, including their status and schedule, a detailed description of this program and the results of analyses shall be submitted subsequently, but early enough to permit NRC staff review and approval prior to the next scheduled restart from a refueling outage. Where the next such restart is scheduled to take place within 90 days, staff review and approval will not be necessary prior to restart from the current refueling outage. An acceptable schedule for submittal of the above information should be arranged with the NRC plant project manager by all licensees to ensure that the staff will have adequate time and resources to complete its review without adverse impact on the licensee's schedule for restart.

(a) The analysis would include an assessment of stability ratios (including flow peaking effects) for the most limiting tube locations to assess the potential for rapidly propagating fatigue cracks. This assessment would be conducted such that the stability ratios are directly comparable to that for the tube which ruptured at North Anna.

(b) The analysis would include an assessment of the depth of penetration of each AVB. The purpose of this assessment is twofold: (1) to establish which tubes are not effectively supported by AVBs and (2) to permit an assessment of flow peaking factors.

(Note: Most steam generators have at least two sets of AVBs. This applies only to the set that penetrates most deeply into the tube bundle.) The methodology used to determine the depth of penetration of each individual AVB shall be described in detail in the written report. The criteria for determining whether a tube is effectively supported by an AVB shall also be identified. (Note: An AVB that penetrates far enough to produce an eddy current signal in a given tube may not penetrate far enough to provide a fully effective lateral support to that tube.)

Response C.2:

A preliminary, in-house analysis of stability ratios was performed and results were reported to the NRC in a meeting on November 19, 1987. Attachment 3 describes a plan which is being proposed for performing the analysis indicated in part (a). The depth of penetration of the AVBs has already been determined. Attachment 4 outlines the method of determining AVB position and shows which tubes may be of concern.

Clearly, full determination of whether any tubes may be susceptible to unstable vibration will not be made until the study outlined in Attachment 3 is completed. When the study is completed, the need for and the timetable of further corrective actions will be determined. This information will be forwarded to you by May 1989 in support of the next refueling outage which is currently scheduled for August 1989. Connecticut Yankee Atomic Power Company (CYAPCO) believes that the safety issue is being addressed by the present enhanced leak rate monitoring program described in Attachment 2.

If there are any further questions, please do not hesitate to contact my staff.

Very truly yours,

CONNECTICUT YANKEE ATOMIC POWER COMPANY

E. J. Mroczka
Senior Vice President

STATE OF CONNECTICUT)
) ss. Berlin
COUNTY OF HARTFORD)

Then personally appeared before me, E. J. Mroczka, who being duly sworn, did state that he is Senior Vice President of Connecticut Yankee Atomic Power Company, Licensee herein, that he is authorized to execute and file the foregoing information in the name and on behalf of the Licensee herein, and that the statements contained in said information are true and correct to the best of his knowledge and belief.

Notary Public
My Commission Expires March 31, 1988

Attachments

cc: U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555

A. B. Wang, NRC Project Manager, Haddam Neck Plant
J. T. Shedlosky, Resident Inspector, Haddam Neck Plant

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Attachment 1

Response to NRC Bulletin No. 88-02

Item A, Denting

Haddam Neck Plant

March 1988

HADDAM NECK STEAM GENERATOR

TOP TUBE SUPPORT PLATE DENTING

The presence of tube support plate denting (Support Plate #4) on both cold and hot legs sides was determined for each tube in Rows 10 to 15 in all four steam generators (SGs).

In order to equate eddy current (ECT) voltage response to dent size (a nominal 1 mil dent produces approximately a 20 volt signal), an in-line dent standard was used during the 1987 ECT inspection. A response of 20 volts or more was identified as a dent. Any tube with less than 20 volt signal was considered nondented.

The results of this review is summarized in Table 1.

In general, most top tube support plate lissajous signals in SG 1 and SG 2 were rotated. This indicates that general uniform tube support plate corrosion exists. Steam Generators 3 and 4 are essentially nondented with essentially no support plate signal rotation.

Table 1 shows that SG 1 and SG 2 are predominantly dented where SG 3 and SG 4 are relatively free from dents.

TABLE 1

1987 STEAM GENERATOR EDDY CURRENT FIELD DATA SUMMARY

DENTING SUMMARY

SG #	# COLD LEG ONLY	# HOT LEG ONLY	# BOTH HOT & COLD LEG	NO DENTS	TOTAL
1	16	321	61	182	580
2	115	51	55	359	580
3	0	10	0	570	580
4	2	16	1	561	580
TOTAL	133	398	117	1672	2320

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Attachment 2

Response to NRC Bulletin No. 88-02

Item C.1, Monitoring

Haddam Neck Plant

March 1988

Item C.1: Monitoring

Connecticut Yankee's Haddam Neck Plant currently uses an enhanced primary-to-secondary leak rate program. The program is intended to ensure that if a rapidly propagating fatigue crack were to occur, the plant power level would be reduced to 50% power or less at least five hours before a tube rupture. This is based on the plant procedure for leakage monitoring, plant technical specifications, and the assumed time-dependent leakage curve of I&E 88-02.

The plant leakage monitoring program is based on periodic measurements of tritium concentrations in primary and secondary systems. Measurements are taken from grab samples of the secondary system blowdown for comparison to primary coolant system results. Sampling frequency is a function of leak rate, at rates of ten gallons per day (gpd) or less samples are taken daily. At rates between 10 and 20 gpd, samples are taken every eight hours. At rates between 20 gpd and 100 gpd, samples are taken every four hours. At rates above 100 gpd, samples are taken every hour.

The estimated measurement error is small - 10% for rates near the technical specification limit of 150 gpd for any one steam generator.

The system is "in service" to meet technical specification requirements. If no reading could be obtained, the limiting condition for operation would require shutdown.

The program also requires data review and trending. Results are reported to station management routinely. If the projection indicates that the technical specification limit will be exceeded, station management is informed as soon as practical.

As shown in Figure 1, the technical specification limit would be exceeded ten hours before rupture for the time dependent leakage curve of I&E 88-02. In the worst case of timing and instrument error, a reading which exceeds the limit would be taken nine hours before rupture. By eight hours before rupture, the reading would have been analyzed so that power reduction would commence. At the administratively specified power reduction rate, 50% power (approximately 300 MWe) would be achieved by five hours before rupture.

It should be noted that this is a very conservative treatment of the assumed time-dependent leakage curve. It assumes worst case timing with concurrent worst estimated measurement error. It takes no credit for trending and assumes the unit would run with leakage just below the allowable limit. Even with this conservative treatment, however, the unit meets the five-hour margin to rupture recommended by I&E Bulletin 88-02.

HADDAM NECK PLANT

PRIMARY-TO-SECONDARY SYSTEM LEAKAGE

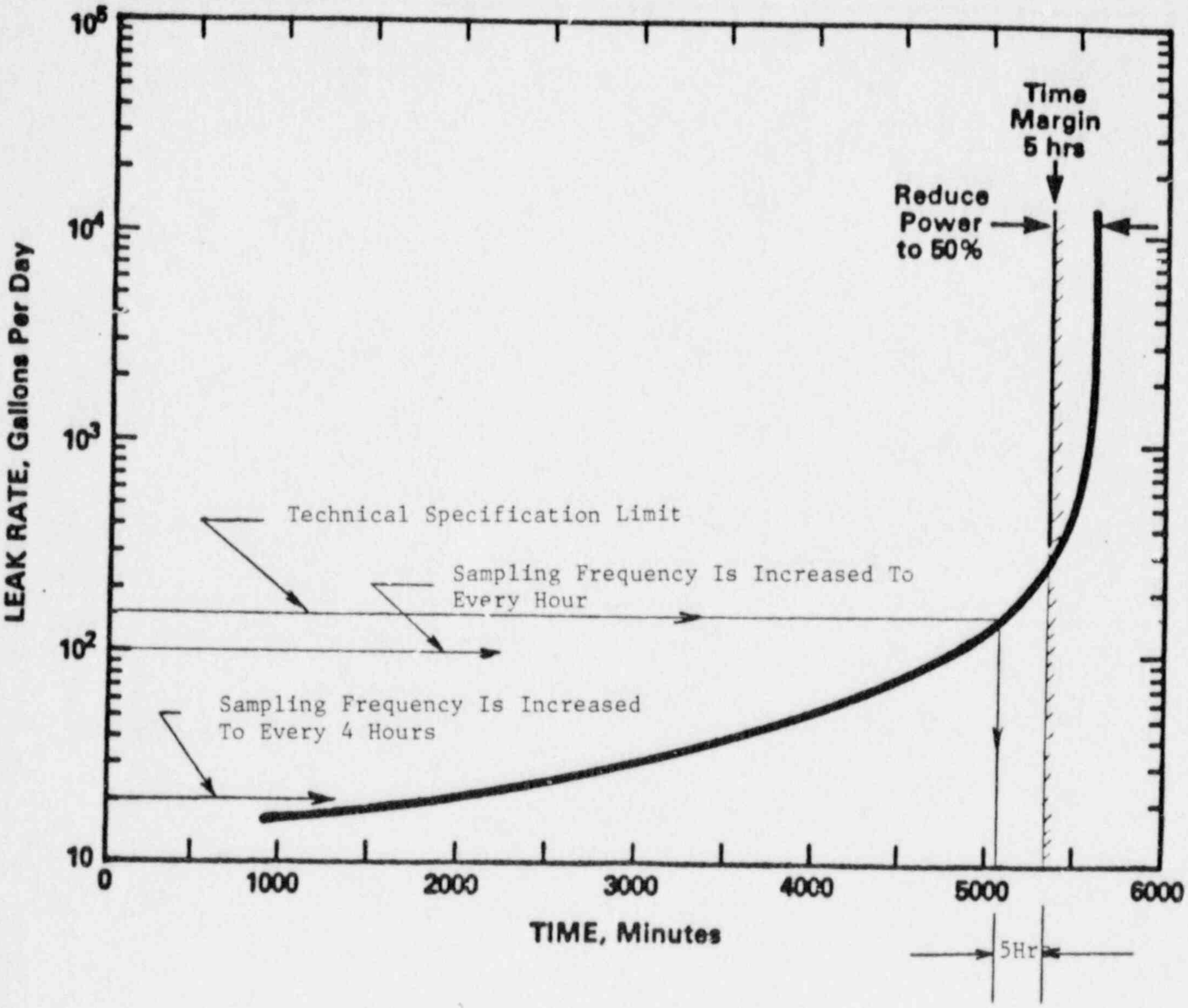

Figure 1 LEAK RATE VERSUS TIME

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Attachment 3

Response to NRC Bulletin No. 88-02

Item C.2.a, Proposed Analyses

Haddam Neck Plant

March 1988

Item C.2.a: Proposed Analyses

In order to assess the stability ratios for the U-bend region of the Haddam Neck - Steam Generator Tubes, the following analysis is proposed:

(i) A detailed thermal hy..aulics evaluation of the Haddam Neck Steam Generators will be performed utilizing one of the state-of-the-art computer codes (e.g., ATHOS, PORTHOS, etc.). The purpose of this analysis is to define the flow field accurately in the U-bend region. Antivibration bars can have a significant effect on the local fluid low velocities. There is no clear cut standard way to incorporate the antivibration bars in the model. Therefore, various techniques for incorporating antivibration bars will be investigated and the most appropriate one will be chosen.

(ii) A detailed finite element analysis will be performed to compute the free vibrations modes and frequencies of the tubes in the U-bend region. The effects of the hydrodynamic coupling will be included using the concept of hydrodynamic mass in both single and two phase conditions. Boundary conditions used in the analysis will account for the tube denting at the support plate.

(iii) Next, the effective velocity and the critical flow velocity at which the tubes become fluid elastically unstable will be determined. The stability ratio is the ratio of the effective cross flow velocity and the critical velocity. These computations are complicated by the flow field that exists in the U-bend region, two phase flow condition and lack of data on damping as a function of denting and the two phase flow condition. The available literature will be surveyed and the most appropriate techniques for accounting for these factors will be utilized.

The stability ratio computations will be provided in sufficient detail to allow direct comparisons with any North Anna analyses.

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Attachment 4

Response to NRC Bulletin No. 88-02

Item C.2.b, Antivibration Bars

Haddam Neck Plant

March 1988

HADDAM NECK STEAM GENERATOR

ANTIVIBRATION BAR DETECTION METHODOLOGY

INTRODUCTION

Haddam Neck (CY) was requested to review the most recent eddy current (ECT) data to determine the exact positioning of the antivibration bars (AVB) for each column of tubes in all four steam generators (SGs).

Since CY's minimum design requirement for AVB insertion depth is Row 14, Row 10 to 15 and selected higher row tubes were identified as needing evaluation.

ANALYSIS DESCRIPTIONS

o Antivibration Bar Detection Methodology

The CY SG ECT data analysis approach for detecting AVB is relatively straightforward. SG ECT inspections at CY typically include a 25 KHz frequency for purpose of sludge height determinations. This frequency was used as the primary frequency for detecting AVBs. Where necessary, 100/25 KHz mix was utilized to eliminate tube deposit noise. Copper interference is not a concern.

For convenience of data presentation, an ECT reporting convention for AVB positioning was established. This convention consists of:

(1) Any tube not supported by any AVB was assigned the code AV0.

(2) A tube supported by only the apex of the lower AVB (only one support location) was assigned AV1.

(3) A tube supported by the lower AVB on the hot and cold legs was assigned AV2.

(4) A tube supported by the two lower AVB insertions and the apex of the upper AVB was assigned AV3.

(5) A tube supported by the upper and lower AVBs on both hot leg and cold leg was assigned AV4.

The results of this analysis for each SG (is plotted in Figures 1 through 4).

Table 1 summarizes the number of "unsupported" tubes in Rows 10 through 17 for each SG. Note that Row 17 tubes were all found to be supported.

Table 2 summarizes the number of tubes which are both dented and unsupported.

Where a tube was supported by only the apex of the lower AVB detailed geometry design layouts were constructed using arc length measurement techniques. The detailed methodology for these arc length measurements is described in Appendix A. From these arc length measurements, detailed scale drawings were constructed to physically layout the AVB/SG tube U-bend relationship (see Figure 4, Appendix A). Along with this data, AVB voltages were measured for additional information.

The AVB signal voltage changes as the AVB-SG tube gap changes. Since 25 KHz was used as the primary frequency to detect AVBs, the possibility of "seeing" an AVB which is not in contact with the SG tube existed. Based upon this, a methodology was developed to measure the effect of this gap on the AVB signal response. The details of this methodology are provided in Appendix B.

o <u>Combining Both AVB and Dent Data</u>

In order to combine both the AVB support and tube denting data in a concise and meaningful manner, the reporting convention previously described for AVBs (e.g., 0, 1, etc.) was combined with the following color coding for denting (refer again to attached Figures 1 through 4):

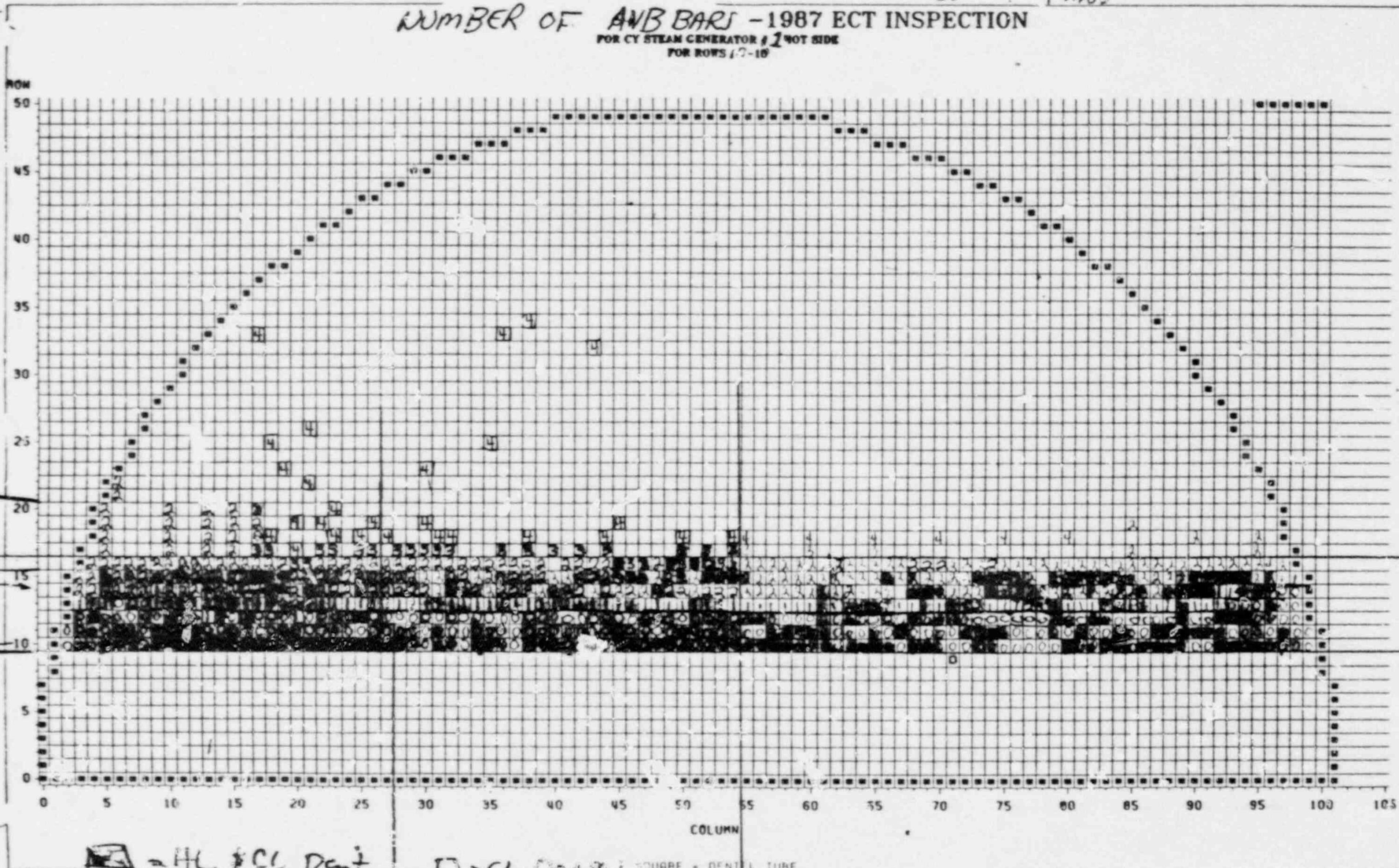
(1) No dent = no color

(2) Hot leg (HL) dent only = blue

(3) Cold leg (CL) dent only = yellow

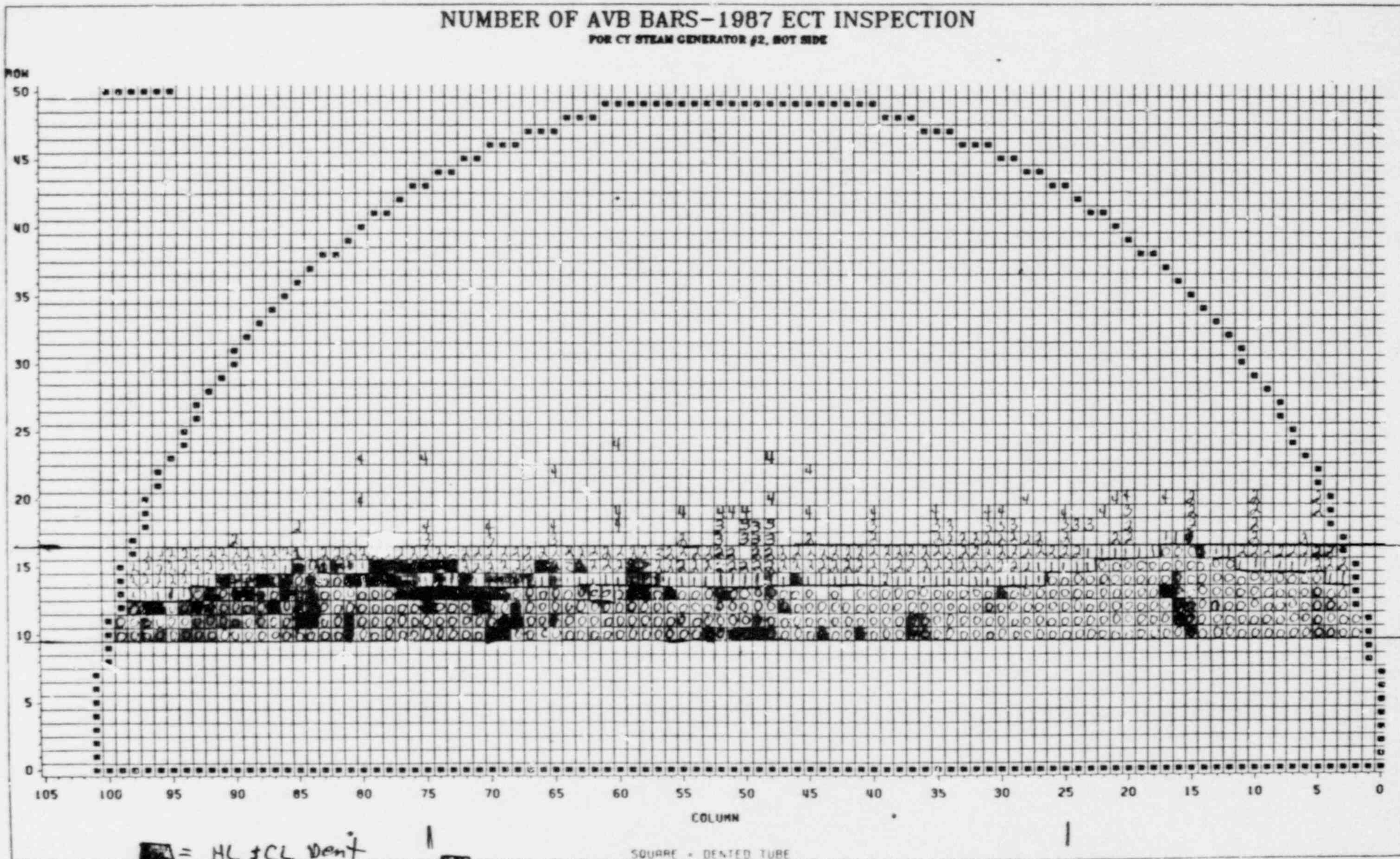
(4) Both HL and CL dent = pink

O = No AVBs
1 = 1 AVB
2 = 2 AVBs
3 = 3 AVBs
4 = 4 AVBs



Based on 1987 ECT Data

10/28/87



= HL & CL Dent

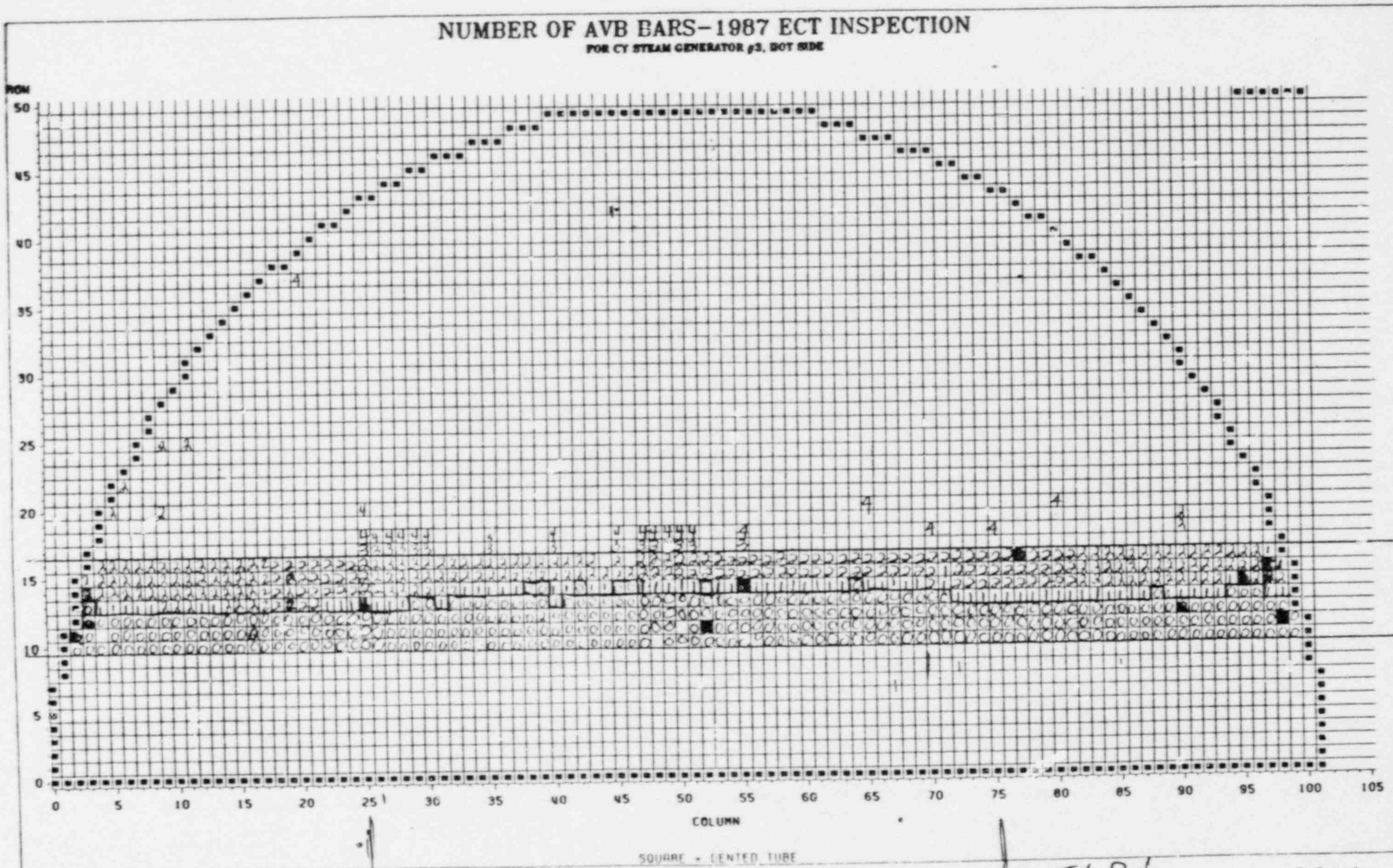
= HL Dent Only

= CL Dent Only

= No Dent

Based on 1987 ECT Data

10/28/87



Based on 1987 ECT Data

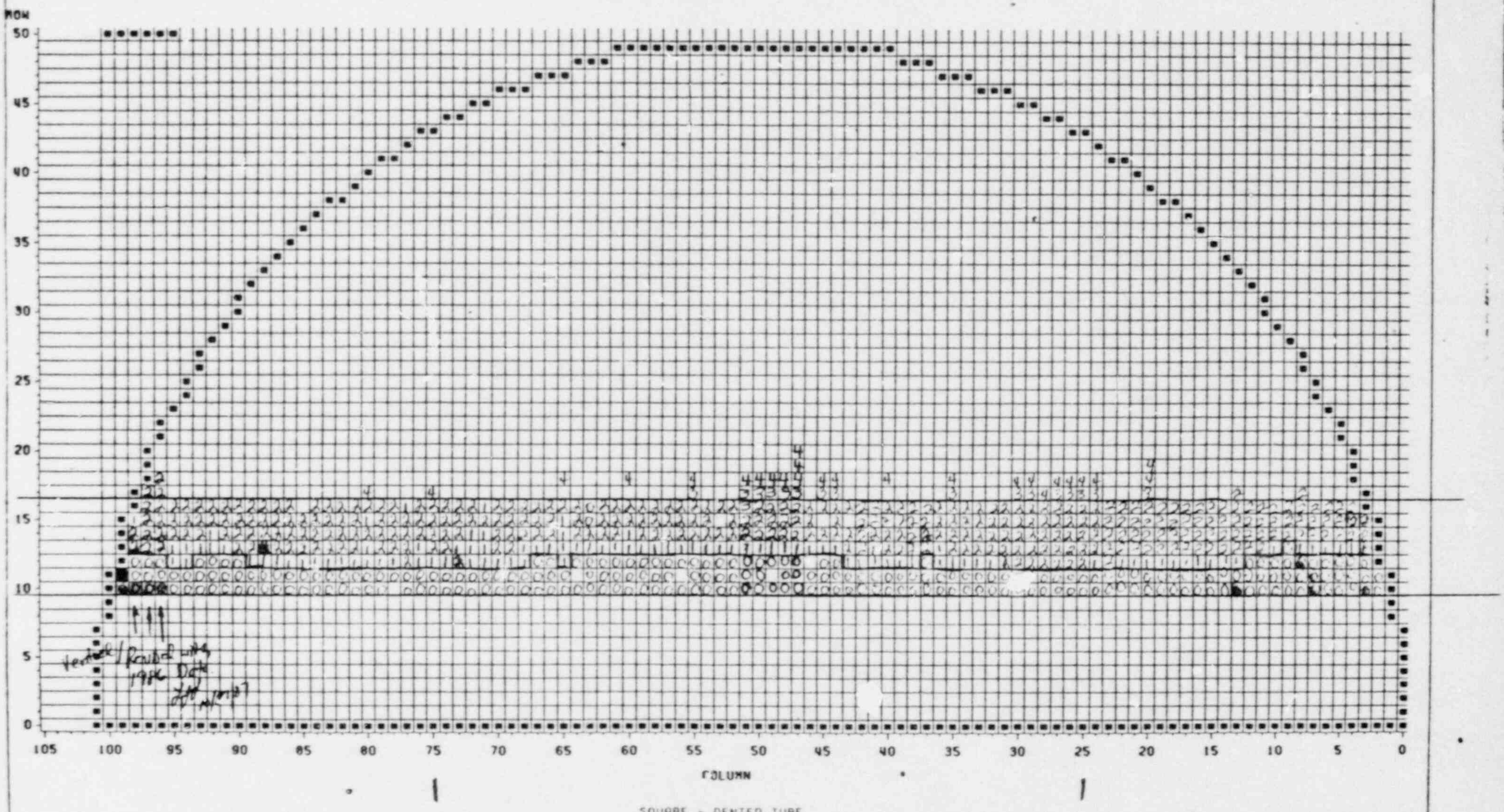
■ = HL Dent Only

□ = No Dent

10/28/87

NUMBER OF AVB BARS–1987 ECT INSPECTION

FOR CY STEAM GENERATOR #4, HOT SIDE



■ = HL & CL Dent
◧ = HL Dent Only
◨ = CL Dent Only
□ = No Dent

Based on 1987 ECT Data

10/28/87

TABLE 1

HADDAM NECK STEAM GENERATOR

NUMBER OF "UNSUPPORTED" TUBES

(ROWS 10 - 17)

ROW #	# OF TUBES IN ROW	Steam Generator #1	#2	#3	#4	TOTAL
10	98	98	98	98	98	392
11	98	98	98	98	98	392
12	96	92	96	96	41	325
13	96	9	91	46	1	147
14*	96	2	30	7	0	39
15	96	0	13	0	0	13
16	94	0	3	0	0	3
17	94	0	0	0	0	0

* MINIMUM DESIGN REQUIREMENT INSERTION DEPTH.

TABLE 2

HADDAM NECK STEAM GENERATOR

NUMBER OF DENTED/UNSUPPORTED TUBES

ROW #	Steam Generator #1	#2	#3	#4	TOTAL
12	60/92	45/96	2/96	1/41	108/325
13	6/9	41/91	1/46	0/1	48/147
14	0/2	9/30	0/7	----	9/39
15	----	2/13	----	----	2/13
16	----	0/3	----	----	0/3
17	----	-----	----	----	-------
TOTAL DENTED AND UNSUPPORTED	66	97	3	1	167/537

APPENDIX A

METHODOLOGY FOR DETERMINING

ACTUAL ANTIVIBRATION BAR GEOMETRIES

INTRODUCTION

The 1987 Haddam Neck Steam Generator (SG) Eddy Current (ECT) Inspection data was utilized to determine the actual CY SG antivibration bar (AVB) positions.

Proximity measurements between each of the AVBs were taken for purposes of reconstructing the actual AVB configuration. This summary describes the methodology used to reconstruct the actual AVB configuration from actual CY SG ECT data.

(1) Calibrate scale between two support plates to a distance of 45.3 inches (i.e. between TSP #3 and TSP #4).

(2) Once scale is calibrated place the cursor at the center of the top (TSP #4) hot leg and zero the scale.

(3) Move the cursor around the U-bend and record the distance where the center line of each AVB appears using the following DDA-4 sheet conventions (refer to Figure 1):

S1 = span from TSP #4 (HL) to AV1

S2 = span from TSP #4 (HL) to AV2

S3 = span from TSP #4 (HL) to AV3

S4 = span from TSP #4 (HL) to AV4

S5 = span from TSP #4 (HL) to AV5

VOLTS Column = inches

(4) Obtain a DDA-4 printout (refer to Figure 2) at each AVB location showing the span location and record the information on the data disk.

(5) Once all span measurements have been completed and recorded on the DDA data disk, print out the complete list of span measurements (Figure 3).

(6) From the DDA-4 generated in (5) calculate the U-bend radius using S5 (span from TSP #4-HL to TSP #4-CL) as follows:

a. The circumference (C) of a circle is defined as

$$C = 2\,(\pi)R$$

where R is the radius

and $C = (2)*(S5)$

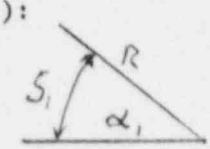
Since S5 represents only <u>half</u> the circumference (the U-bend arc length) the radius is calculated as:

$$\text{Radius } (R) = S5/(\pi)$$

or

$$(R) = \frac{\text{Span from TSP \#4-HL to TSP \#4-CL}}{(\pi)}$$

(7) Once the spans for each AVB bar have been measured and the radius (R) for each row has been calculated, the angles (α_1 , α_2 , α_3 , α_4) from the TSP #4-HL can be calculated (refer to Figure 1):



$$\alpha_1 \text{ (degrees)} = \frac{57.296\ (S1)}{\pi}$$

Example #1:

$$\alpha_1 \text{ (SG \#2 - R17/C85)} = \frac{57.596\ (30.1)}{21.18}$$

$$\alpha_1 \text{ (SG \#2 - R17/C85)} = 81.4 \text{ degrees}$$

Therefore the angle (α_1 ,) from TSP #4-HL to AVB #1 for Tube R17/C85 is 81.4 degrees.

(8) Repeat Step (7) for each row/column combination as necessary.

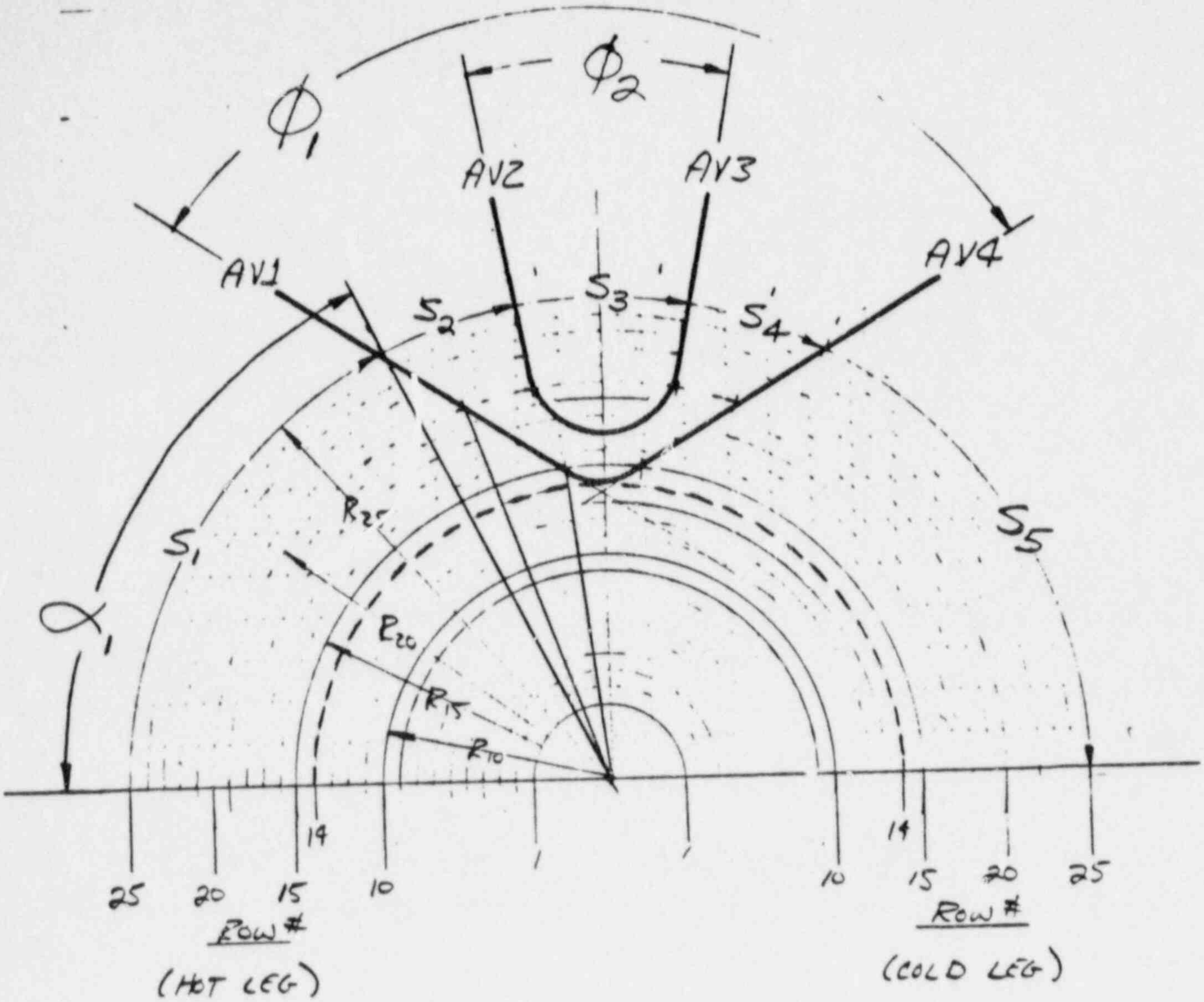
(9) Repeat Steps (7) and (8) for Rows 15, 20, and 25 to establish 3 points for constructing a straight line projection of the AVB bar.

(10) This data is then drawn to scale (1:4) as in Figure 4 using the correct SG tube, AVB bar diameter and AVB bend radius.

NOTE: In the example shown the center line of the AVB is **BELOW** the SG tube radius center line indicating that this particular tube is fully supported.

(11) Repeat Steps (1) through (10) as necessary for each column of interest.

(12) Once the detailed scale drawing has been constructed the degree of AVB support can be verified.



Φ_1
Φ_2
AV1
AV2
AV3
AV4
S_1
S_2
S_3
S_4
S_5
α_1
R_{25}
R_{20}
R_{15}
R_{10}
25 20 15 10 1 14
1 10 14 15 20 25
ROW #
(HOT LEG)
ROW #
(COLD LEG)

Figure 1

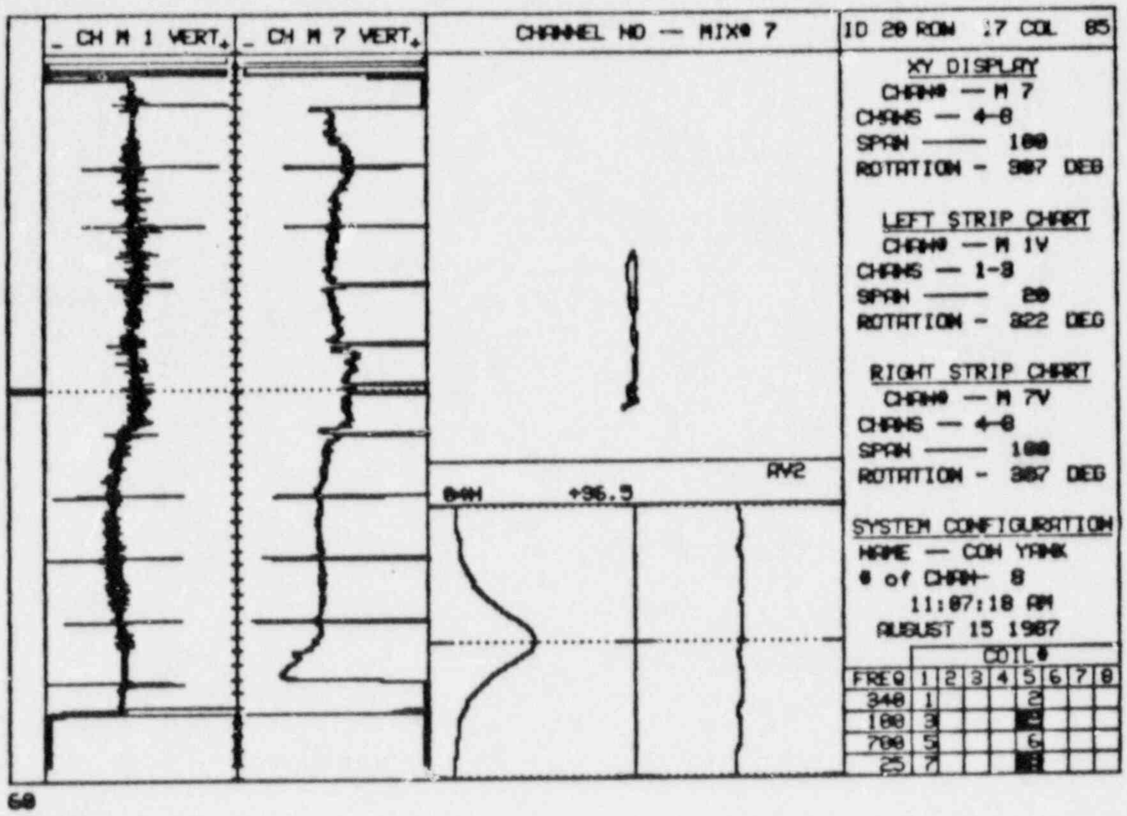

CH M 1 VERT
CH M 7 VERT
CHANNEL NO — MIX# 7
ID 20 ROW 17 COL 85
XY DISPLAY
CHAN# — M 7
CHANS — 4-8
SPAN — 100
ROTATION - 307 DEG
LEFT STRIP CHART
CHAN# — M 1V
CHANS — 1-8
SPAN — 20
ROTATION - 322 DEG
RIGHT STRIP CHART
CHAN# — M 7V
CHANS — 4-8
SPAN — 100
ROTATION - 307 DEG
SYSTEM CONFIGURATION
NAME — CON YANK
# of CHAN- 8
11:07:18 AM
AUGUST 15 1987
COIL#
FREQ 1 2 3 4 5 6 7 8
340 1 2
100 3
700 5 6
25 7
AV2
+96.5
60

figure 2.

figure 3-

PLANT	UNIT#	S/G	LEG	REEL	TO	REEL	DATE
CONN. YANKEE	1	1	INLET	MULT			10/14/87

ID	ROW	COL	VOLTS	DEG	%	CH#	LOCATION	EXTENT
							START S/G #1 PROXIMITY MEASUREMENTS	
							S1=SPAN FROM 04H TO AV1 S2=SPAN FROM 04H TO AV2 S3=SPAN FROM 04H TO AV3 S4=SPAN FROM 04H TO AV4 S5=SPAN FROM 04H TO 04C VOLTS COLUMN= INCHES	
10	10	40	42.3	S 5				
10	14	40	54.9	S-5				
			24.8	S-1				
			30.0	S-4				
10	20	40	27.7	S-1				
			32.5	S-2				
			41.0	S-3				
			46.5	S-4				
			73.8	S-5				
10	24	40	30.0	S-1				
			38.0	S-2				
			48.4	S-3				
			57.2	S-4				
			86.3	S-5				
10	10	41	42.6	S-5				
10	14	41	25.3	S-1				
			30.5	S-4				
			55.6	S-5				
10	20	41	27.7	S-1				
			32.2	S-2				
			40.7	S-3				
			46.5	S-4				
			73.7	S-5				
10	24	41	30.2	S-1				
			37.9	S-2				
			48.3	S-3				
			57.5	S-4				
			86.8	S-5				
10	10	42	42.9	S-5				
10	15	42	25.7	S-1				
			33.6	S-4				
			59.0	S-5				
10	20	42	28.0	S-1				
			32.5	S-2				
			41.0	S-3				
			47.1	S-4				
			74.4	S-5				
10	25	42	30.6	S-1				

PAGE 1 OF 7	EVALUATOR	LEVEL

(Column #15)

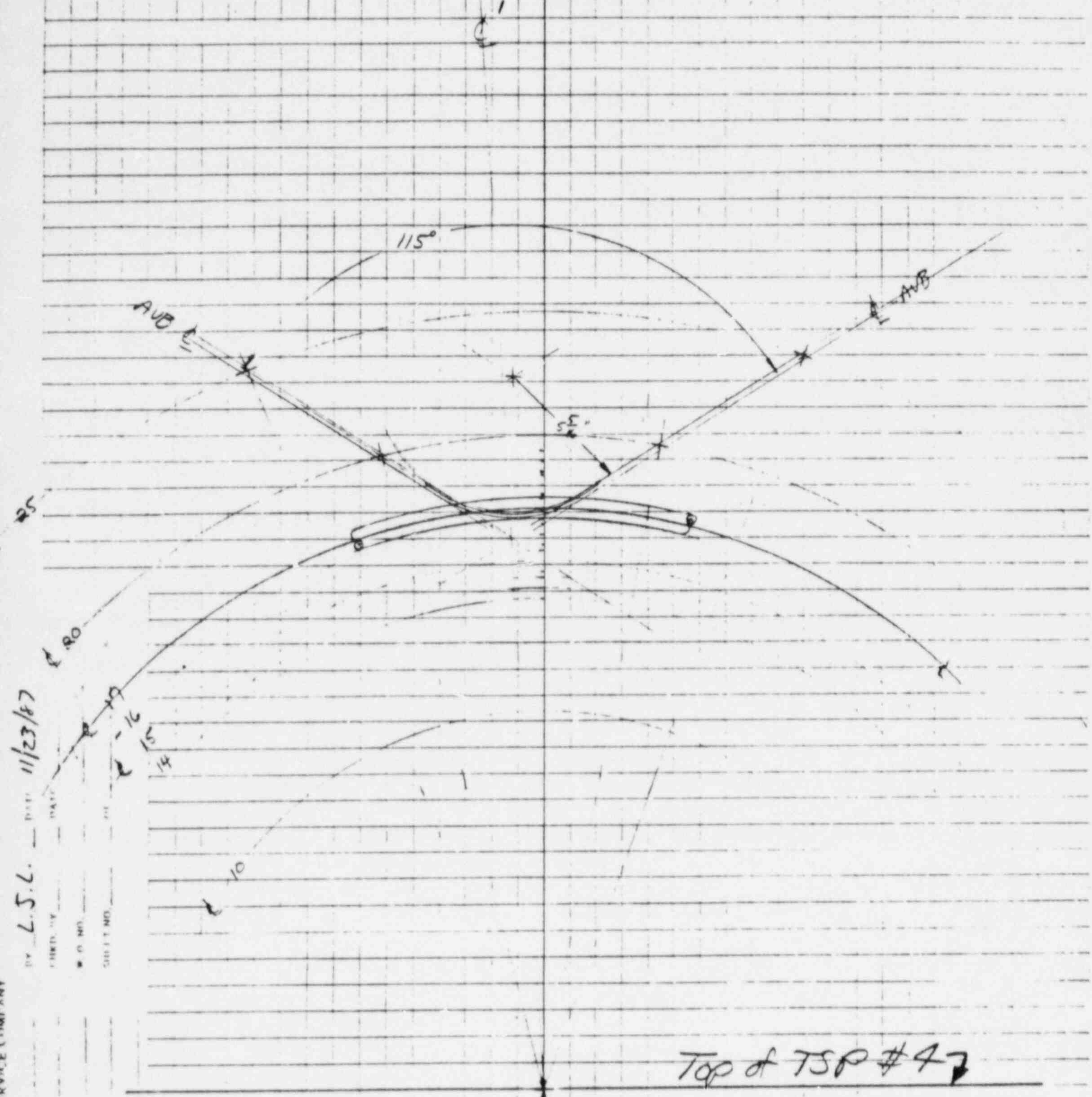


Figure 4

Scale 1:4
L.S.L.

NORTHEAST UTILITIES SERVICE COMPANY
Connecticut Yankee
#2 AVB Locations
(Column #15)
BY L.S.L. DATE 11/23/87

APPENDIX B

METHODOLOGY FOR DETERMINING

ANTIVIBRATION BAR OFFSET

AS A FUNCTION OF AVB VOLTAGE RESPONSE

INTRODUCTION

During a review of the Haddam Neck Steam Generator (SG) Antivibration Bar (AVB) Data Eddy Current Test (ECT) data, questions were raised about the ability of ECT to "see" AVB bars. Since standard ECT bobbin probes cannot determine the exact position of the AVB bar relative to the tube the position of the AVB bar in relation to the center line of the tube needed to be determined.

It is known that the insertion depth of each AVB can vary, and that the degree of insertion depth can change the ECT voltage response. As the AVB bar gets further away from the SG tube the AVB bar voltage response is reduced. The degree to which the ECT probe voltage response changes depends on several variables:

1. ECT probe diameter and type

2. Test frequency

3. SG tube diameter and wall thickness

4. Level of noise (both from the tube and from any deposits on the tube)

5. Size of the AVB bar

6. Material of the SG tube and AVB bar

7. Distance of AVB bar from the SG tube

An experiment was conducted to determine what affect Item 7 had on ECT voltage response. Since signal amplitude can be measured at each AVB intersection, a qualitative assessment can be made as to whether a SG tube is adequately supported by an AVB.

The following describes the methodology used to determine the affect of AVB distance from a SG tube using a simple lift-off experiment.

Figure 1 is a sketch illustrating the relationship between the ECT probe, SG tube and the AVB bar. Note that as the AVB insertion position (offset) varies, the gap between the OD of the SG tube and the AVB bar also varies. This relationship between the AVB gap and the AVB offset is plotted in Figure 2. It is important to note that as the AVB offset increases, the gap between the OD of the SG tube and the AVB also increases.

Based upon this relationship, a mock-up was constructed using a CY SG ECT calibration standard (.055 inches x .640 inches ID) of Inconel 600. A 1/4 inch round carbon steel bar was used to simulate a SG AVB. Plastic shims were used to vary gap size between the SG tube and the simulated AVB without interfering with the ECT signals (Figure 3).

(1) The ECT equipment was set-up using a .560 probe (typical of that used at CY), the CY SG calibration tube and a round 1/4 inch diameter carbon steel bar to simulate CY's round AVBs.

(2) The frequencies used were the same as those used during the most recent 1987 ECT inspection.

(3) Calibration was preferred using a carbon steel support ring where the support plate signal was set to 6.0 volts on the 340 KHz (diff) channel.

(4) To minimize the effect of probe motion, the calibration standard with the probe inserted was placed on a bench and the simulated AVB was moved past the probe. The ECT response was then recorded using a MIZ-18 and DDA-4 for analysis.

(5) With each successive pass of the simulated AVB, another plastic shim was added to increase the gap between the AVB and the OD of the SG tube.

(6) Steps (4) and (5) were repeated until the gap exceeded approximately 0.2 inches. The ECT data was then analyzed using an amplitude (voltage) analysis technique for each pass of the AVB bar.

The results of this ECT amplitude analysis is plotted in Figure 4. Note that the voltages recorded are for one(1) AVB; the actual SG has two AVB bars, one on each side of the SG tube. The field voltages, therfore, under similar conditions would be approximately double. Also note that the absolute voltage response with the AVB in contact is 1.56 volts or 3.1 volts for two AVBs. This indicates that under ideal conditions (25 KHz, clean tube with no deposit or U-Bend interference) a 1/4 inch round carbon steel bar at right angles to the SG tube axis produces a signal amplitude of approximately 3 volts.

The actual SG condition may have the AVB bar at various angles in relation to the SG tube axis. This study did not test all of these variables.

The typical CY ECT data has general noise levels (deposits, geometry, etc.) on the order of 2 to 3 volts at 25 KHz. Because of this, an AVB bar voltage response of 3 volts or more is necessary to "see" the AVB. The typical AVB signal voltages for CY are on the order of 3.5 to 9 volts depending on the actual AVB/SG tube physical relationship. An AVB inserted in a manner similar to as that illustrated in Figure 6 would produce a large AVB voltage response.

In order to relate AVB offset to AVB signal voltage, Figure 2 and Figure 4 were combined to generate Figure 7.

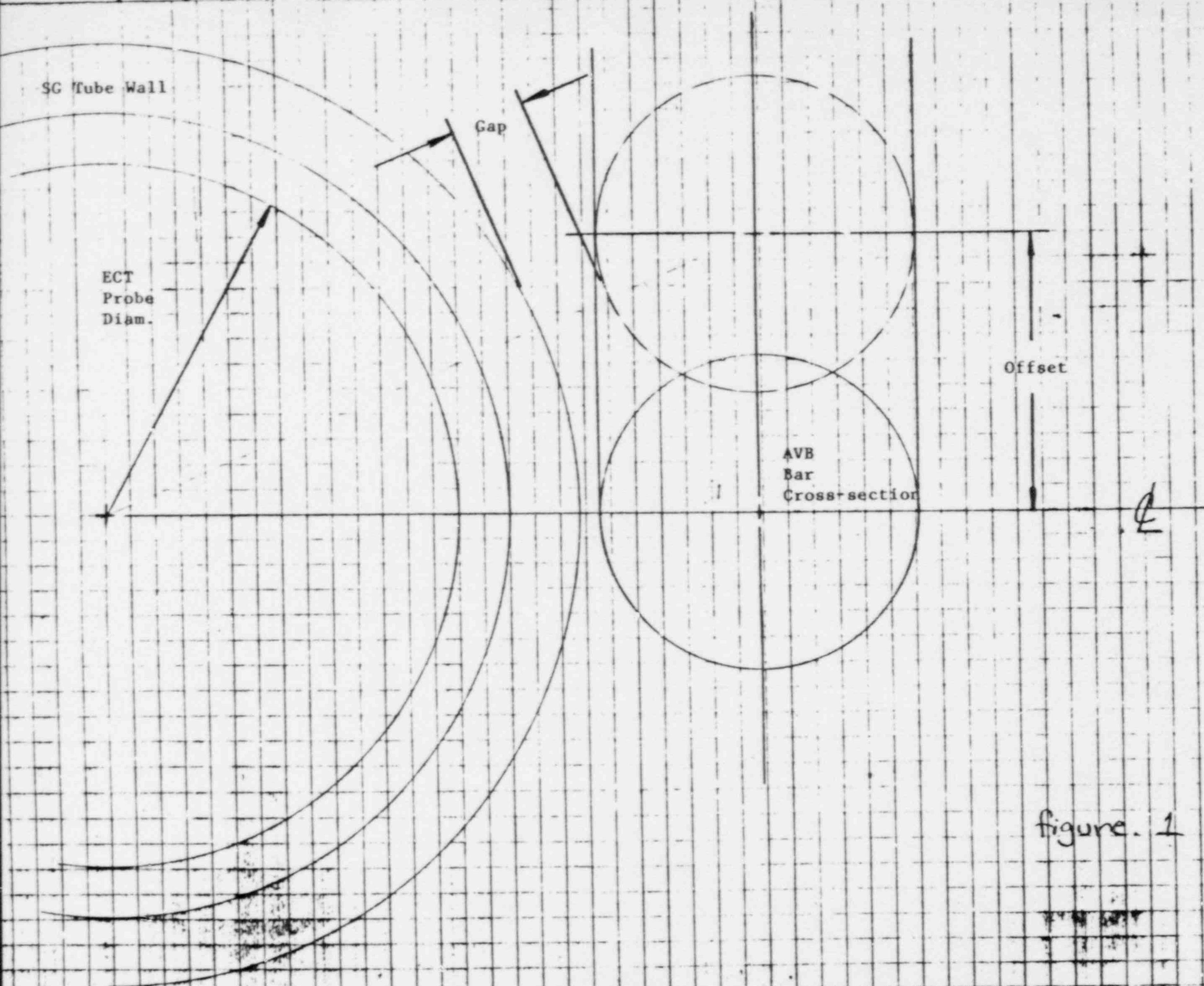


figure. 1

OFFSET VERSES AVB GAP

.560 INCH PROBE / 25 KHZ FREQUENCY

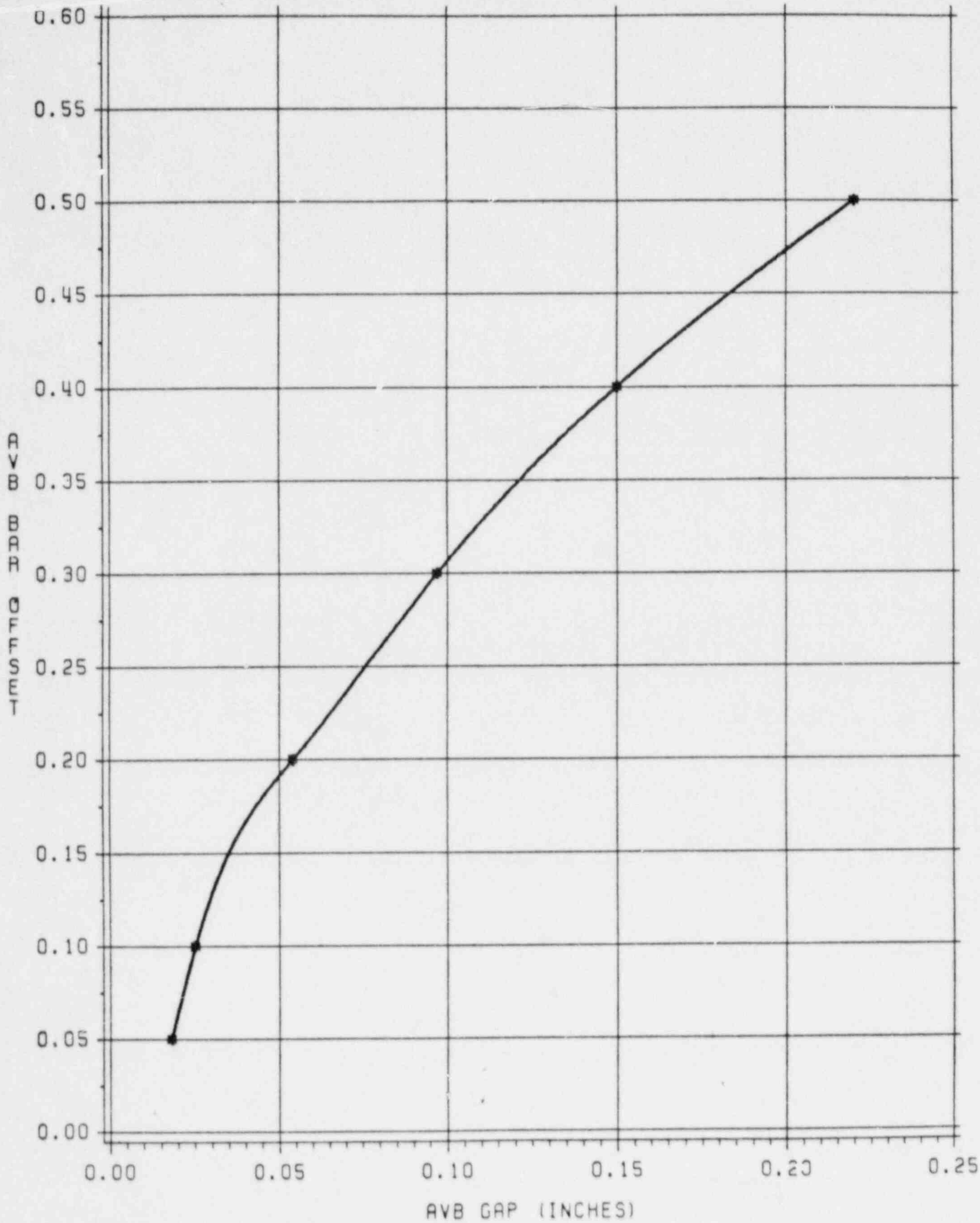


figure 2.

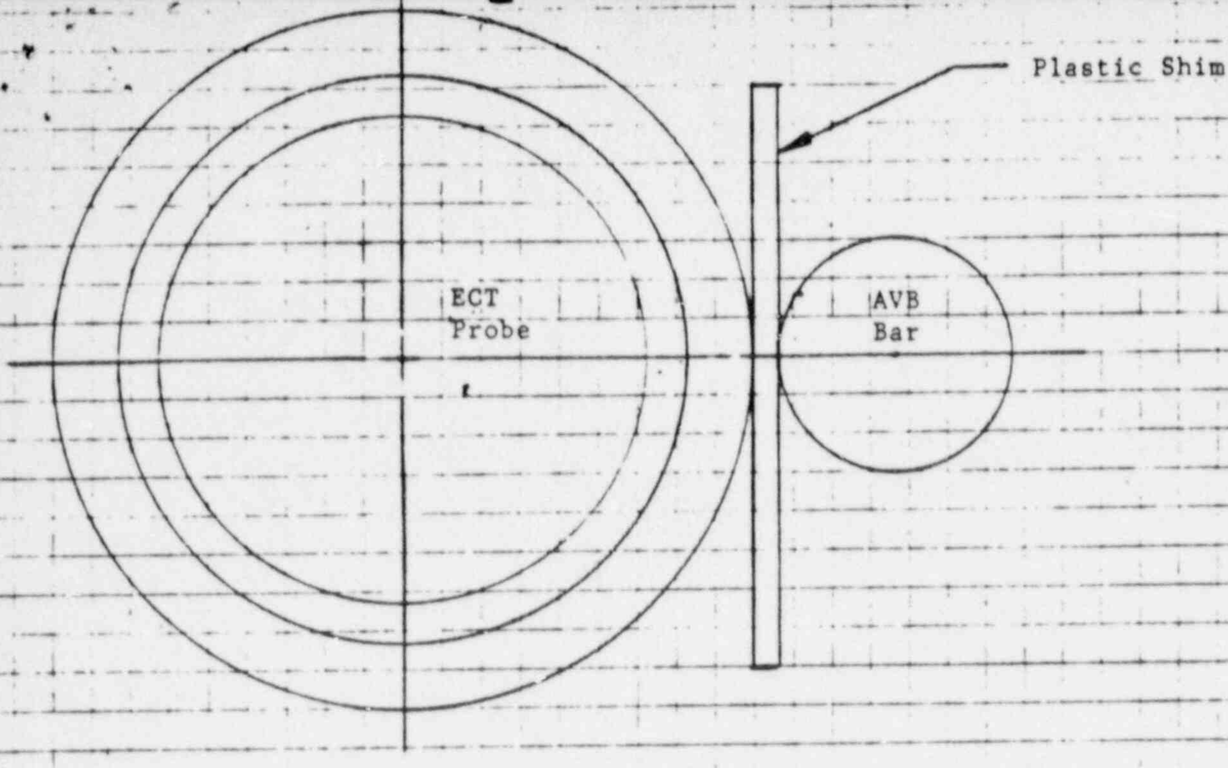
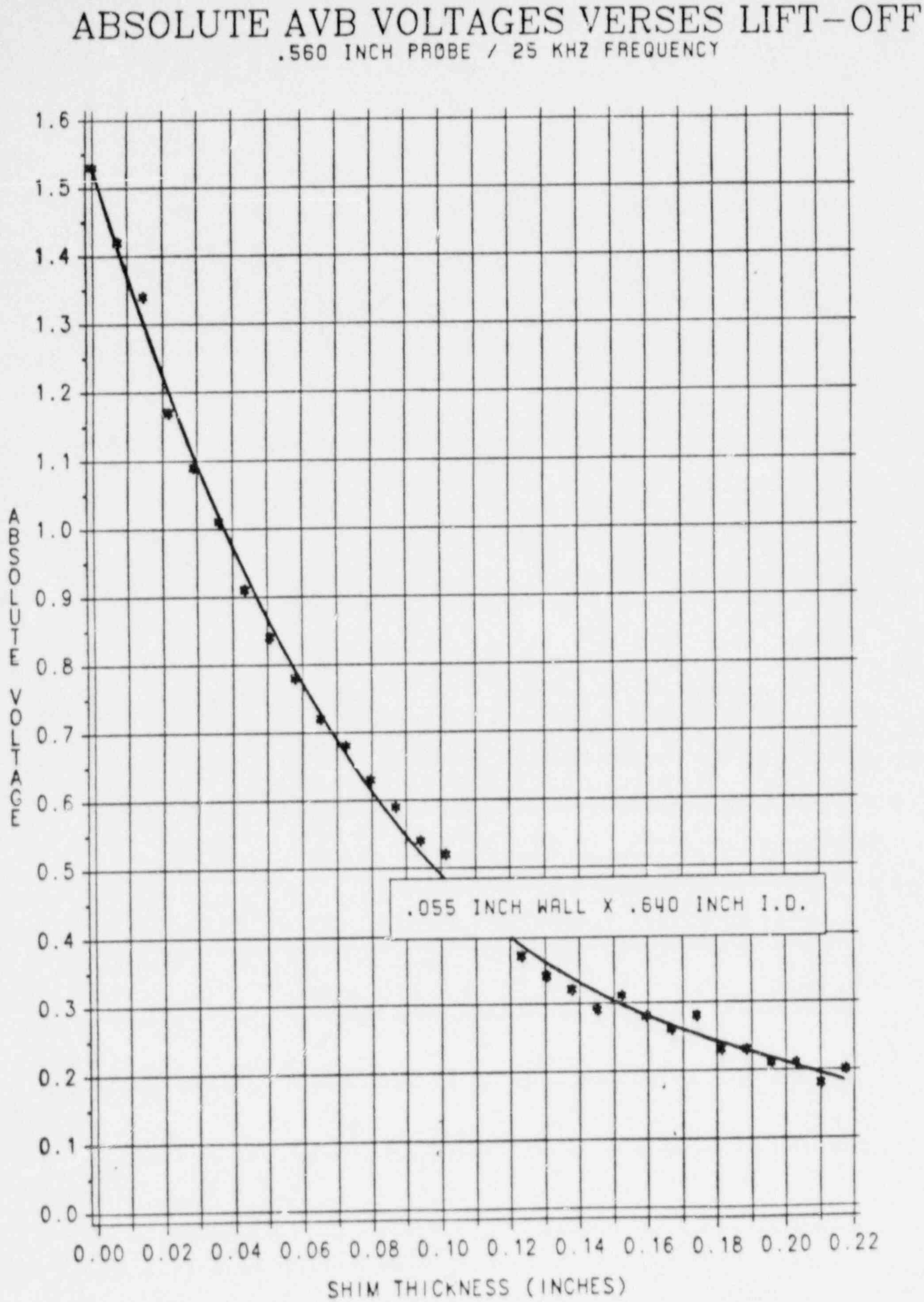


Figure 3



ABSOLUTE AVB VOLTAGES VERSES LIFT-OFF
.560 INCH PROBE / 25 KHZ FREQUENCY
ABSOLUTE VOLTAGE
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
.055 INCH WALL X .640 INCH I.D.
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22
SHIM THICKNESS (INCHES)

figure 4.

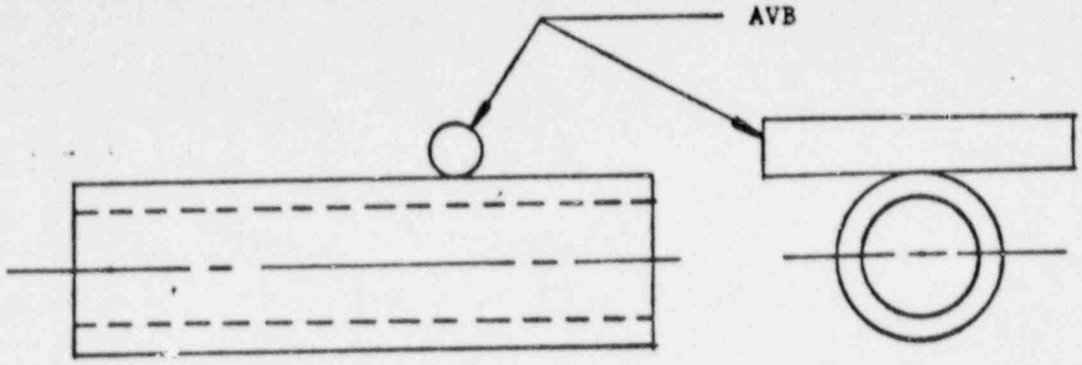


figure 5.

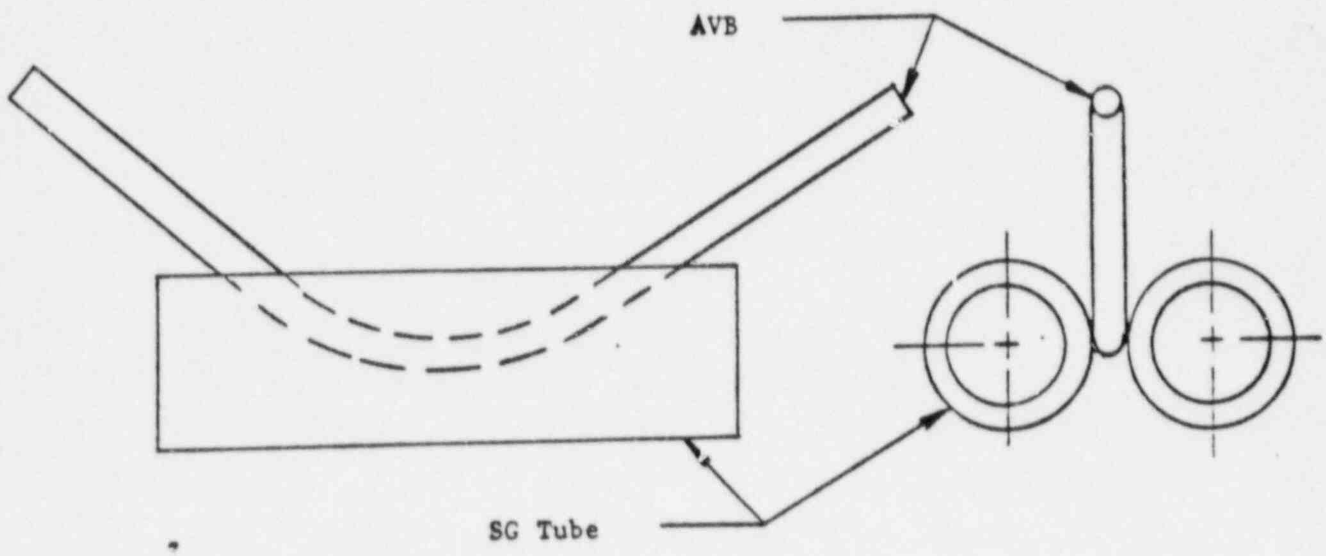


figure 6

AVB VOLTAGES VERSES AVB OFFSET

.560 INCH PROBE / 25 KHZ FREQUENCY
WITH 95% CONFIDENCE LIMITS

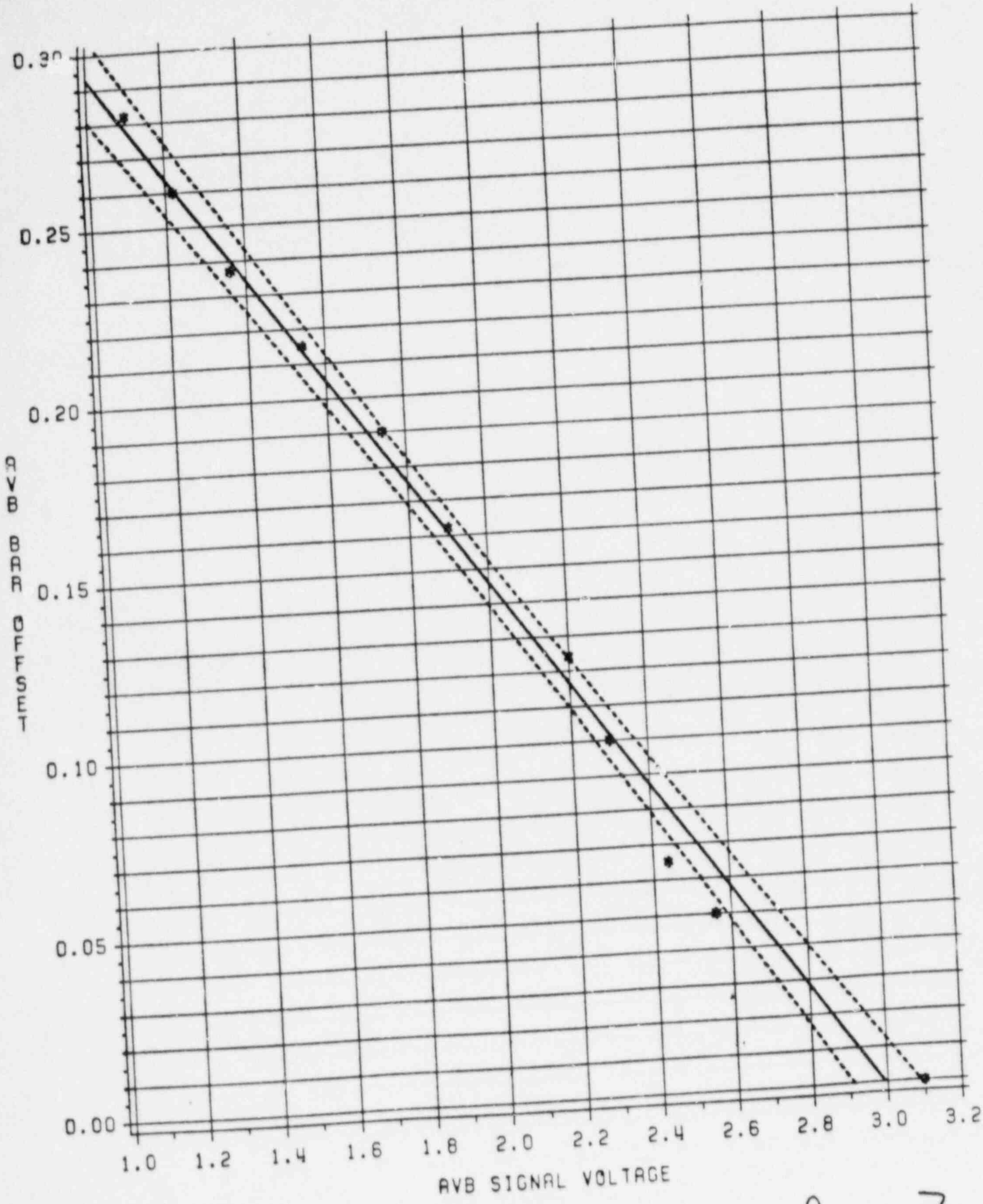


figure 7.