CAROLINA POWER AND LIGHT COMPANY

H. B. ROBINSON SEG PLANT, UNIT NO. 2

1982 REFUELING OUTAGE

STEAM GENERATOR INSPECTION

REPORT

SEPTEMBER, 1982

Prepared by E. V. Paine

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I.1 Eddy Current Inspection of Steam Generator (S/G) Tubing

I.1.1 Inspection Scope

The initial inspection sample selected consisted of all unplugged tubes in each S/G. Each tube was to be inspected full length (tube end to tube end). This was accomplished with the exception of eight tubes in "B" S/G which were inspected through the top support plate from each side but not through the U-bend region. These tubes, R1C1, R1C2, R1C40, R4C43, R8C45, R8C46, R9C47 and R1C48 are plotted on Figure I.1.1-1. These tubes were hand probed at the end of the inspection period, and the difficulty encountered due to probe friction did not warrant the radiation exposure required for the full length inspections. Also, these tubes are all located in a region which has never experienced U-bend degradation in any H. B. Robinson S/G. In addition, one tube in "C" S/G (R9C29) would not pass an eddy current probe thru the full tube length. (See Section II.1)

I.1.2 Inspection Technique

The inspections were performed using multi-frequency eddy current equipment. The inspection frequencies utilized were 400 KHz differential, 200 KHz differential, 10 KHz differential and 100 KHz absolute. Various signal frequency mixes were utilized to aid in the detection of tube wall degradation.

I.1.3 Results

The results of the eddy current inspections indicated the presence of degraded and/or defective tubing in four distinct regions of the S/G tube bundles:

I.1.3.a U-bend Region

The U-bend section of tubing in some peripheral tubes exhibited wall degradation typical of phosphate thinning. This occurred primarily on the hot leg side of the S/G's below the #3 anti-vibration bars down to 2 1/2 inches above the sixth support plate (beginning of the bend transition). The same general groups of peripheral tubes also exhibited thinning (not fretting) at some antivibration bar contact points.

I.1.3.b Top of the Tubesheet/Above the Tubesheet (TTS/ATS) Region

The central area of the tube bundle on the inlet and outlet sides of the S/G's exhibited tube wall thinning believed to be due to phosphate corrosion in the length of tubing from the top of the tubesheet up to approximately 15 inches above the tubesheet. This corrosion is attributed to the presence of phosphate rich sludge in the S/G, and the region affected is consistent with the region where sludge accumulation is anticipated.

I.1.3.c Crevice Region

The central region of the tube bundle on the inlet side (hot leg) of the S/G's exhibited corrosion

indicative of a cracking mechanism in the unrolled length (crevice) of tubing in the tubesheet. This is assumed to be intergrannular attack (IGA) consistent with the degradation observed in the same region of a tube sample removed from the "B" S/G in August, 1981.

I.1.3.d Tube Support Region

The section of primarily peripheral tubes which pass through tube support plates exhibited tube wall degradation at or just above the support plates on the inlet and outlet sides of the S/G's. The statistical spread of the eddy current indications is indicative of a thinning mechanism. Therefore, the degradation is attributed to phosphate thinning.

A complete listing of all eddy current results for each S/G is provided in Attachment #2.

I.1.4 Evaluation of the Eddy Current Results

Review of the inspection results and calculated corrosion rates revealed a continuation of tube wall corrosion in some of the regions where corrosion and tube degradation have occurred in the past. With the exception of the tubesheet crevice region, the ongoing corrosion appears to be a thinning process. The cracking phenomenon previously experienced above the tubesheet appears to have been completely arrested by the current low temperature program

(as outlined in our submittal dated August 21, 1981). This conclusion is supported by the distribution of the eddy current indications with respect to number and size. This distribution is depicted in Figures I.1.4-1 through I.1.4-6.

However, the thinning corrosion rates for some of the TTS/ATS regions are higher than those observed for recent past operating periods. This is believed to be due to the reduced temperature program which results in lower secondary temperature and correspondingly higher phosphate concentrations.

No significant corrosion appears to have occurred in either the U-bend or tube support plate region in any of the steam generators.

Corrosion appears to have continued with little change from its previously observed rate in the tubesheet crevice region in spite of the low temperature operation. However, for the period from September 1, 1981 to November 6, 1981, the unit was operated with a T_{HOT} of $575^{o}F$ whereas T_{HOT} was reduced to $560^{o}F$ for the period of November 17, 1981 until February 26, 1982. Therefore, the observed crevice corrosion could be attributed to the residual effects of previous high temperature operation at $575^{o}F$ T_{HOT}, and can be expected to decrease during cycle 9 when T_{HOT} will be limited to $560^{o}F$.

I.1.5 Tube Wall Corrosion Rates

S/G tube wall corrosion rates have been calculated for the U-bend region and the TTS/ATS region. Corrosion rates were calculated by comparison of eddy current indications between sequential inspections. Indications which were 20% or greater in both inspections were utilized to make these calculations. Also, indications which exceeded the plugging limit were not utilized as the affected tubes are no longer in the population subject to continued corrosion. The eddy current indications used in the corrosion rate calculations were based on the most recent inspection April 1982, and two previous inspections, May 1981 and August 1981. Two previous inspections were used because not all of the S/G tubes were inspected in August 1981 and, therefore, some comparisons had to be made with the May 1981 inspection. The overall corrosion rates were conservatively calculated since the corrosion period used for all tubes was assumed to be for the shorter operating period between inspections, i.e., the period from August 1981 to April 1982. This resulted in a corrosion period of 95 Effective Full Power Days (EFPD). The calculated corrosion rates are provided in Figure I.1.5-1.

I.1.6 Return to Power Evaluation

An evaluation has been performed to determine the maximum safe operating period for the H. B. Robinson S.E. Plant

S/G's. This evaluation was based on the largest corrosion rate, assuming continued low temperature operation which essentially eliminates the potential for above-the-tubesheet Stress Corrosion Cracking. Since the IGA observed in the tubesheet crevice region does not represent a safety concern due to the capture of the tube by the tubesheet, the limiting case for establishment of a safe operating period is the worst case thinning corrosion above the tubesheet.

I.1.6.a Corrosion Allowance

The corrosion allowance has been calculated using the Technical Specification required 47% plugging limit and the most limiting tube wall required to maintain integrity, which in the case of H. B. Robinson is for normal operating conditions.

Members of the staff have requested that the normal operating condition with a safety factor of 3 be used to determine the corrosion allowance. This results in a minimum tube wall thickness of 42% being required for tube integrity. While CP&L believes that this approach is overly conservative, calculations were done using the 42% remaining tube wall value. A corrosion allowance (tube wall available for corrosion) of 11% has been calculated using this criteria (100% [original wall thickness] - 47% [worse case tube remaining in service] - 42% [required remaining tube wall thickness] = 11% [corrosion allowance]. This 11% corrosion allowance

figure has been used in Section I.1.6.b to determine the maximum safe operating period. It should be noted that use of a factor of safety of 2 would yield a conservative corrosion allowance of 25%.

Previous discussions of corrosion allowance have included a 9% factor for potential eddy current error. Westinghouse has evaluated the basis and need for this factor for the case of thinning type corrosion. This evaluation revealed that thinning corrosion is consistently overestimated by the eddy current techniques utilized and that a 9% allowance is overly conservative and unnecessary in this case. Therefore, this 9% allowance has not been included in these corrosion allowance calculations. The detailed evaluation performed by Westinghouse is provided in Attachment #1.

I.1.6.b <u>Predicted Corrosion Rates vs. Corrosion Allowance</u>

The most limiting corrosion rate calculated (as listed in Table I.1.5-1) was 1.14% per Effective Full Power Months (EFPM) for the "C" S/G Outlet TTS/ATS region. Based on this corrosion rate and the 11% corrosion allowance, the S/G's can be safely operated for 9.6 EFPM. This translates to 11.9 calendar months at 81% power ($T_{HOT} = 560^{o}F$). Since the expected cycle life for cycle 9 is 10.8 EFPM, an eddy current inspection prior to the end

of the operating cycle is warranted. This inspection will be performed, as required by License Condition 3.I.1.a, prior to exceeding 6 EFPM to ensure tube bundle integrity.

I.2 Secondary Side Inspection

I.2.1 Inspection Scope

Based on recent industry experiences and a review of previous H. B. Robinson S/G data for suspicious plugging patterns, the secondary side of "B" S/G was inspected for foreign objects capable of causing damage to the tube bundles. The region inspected was the annulus between the outer shell and the tube bundle to a height of approximately 8" above the tubesheet. This region of inspection also included a depth of several tubes into the tube bundle. In addition, the tube lane of all three S/G's was inspected prior to close out of the secondary side in accordance with normal site practices.

I.2.2 Inspection Technique

This inspection was performed visually using mirrors and a fiberscope. The tube lane was inspected by QA personnel per their visual inspection procedures.

I.2.3 Inspection Results

This inspection verified that there was no evidence of mechanical damage on the tubes in the suspected plugging region and that there were no foreign objects capable of causing damage to the tube bundle in the region inspected. The inspection did reveal the presence of three pieces of wire approximately 1 inch long and 1/32 inch in diameter. A review of these pieces by CP&L and Westinghouse indicated that they presented no threat to tube bundle integrity and, therefore, were not removed.

II. TUBE BUNDLE REPAIRS

II.1 Mechanical Tube Plugging

Mechanical tube plugging was performed to remove from service all tubes with ECT indications greater than 47%. This plugging limit is consistent with plant Technical Specification requirements and supported by these evaluations. One additional tube in "C" S/G was plugged due to a 41% indication in the tubesheet crevice region for unit reliability reasons. Also, one tube in "C" S/G which would not pass an eddy current probe thru the full tube length was mechanically plugged. A list of tubes plugged is provided in Figure II.1-1. (It should be noted that eight of the tubes listed were plugged due to plugging errors during this and previous outages.)

II.2 Weld Repairs

Weld repairs were performed on three tube ends in the inlet (hot leg) side of "A" S/G. These repairs were required due to minor leakage from tubes previously removed from service by explosive plugging. These tubes were originally plugged due to ECT indications in excess of the plugging limit. The leakage is attributed to the explosive plugs not being fully seated during initial installation, which was not evident until the tube walls were fully penetrated and the plug began to leak. A list of the affected tubes is provided in Table II.2-1 below.

Table II.2-1

List of Weld Repaired Tubes

ROW	COLUMN	DATE PLUGGED	INDICATION
8	50	5/72	75%
8	52	5/72	60%
8	30	5/72	85%

II.2 Weld Repairs (Continued)

The repair technique on these three tubes consisted of the following:

1. Removal of the tube end projecting from the tubesheet, the tube to tubesheet weld, and a portion of the explosive plug by machining.

2. Installation of an inconel plug into the tubesheet hole and manual welding of the plug to the tubesheet clad.

3. Verification of an acceptable repair via a visual inspection and a leak check with a secondary to primary water pressure of 200 psi. Acceptable weld repairs were achieved on tubes R8C50 and R8C30. However, R8C52 exhibited leakage after each of two repair attempts. Subsequent to the second repair attempt, the expected leak rate at operating conditions was calculated based on the observed leak rate test. The expected leak rate was calculated as 3.5% of the Technical Specifications limit. Also, the assumed leak path geometry was evaluated and the conclusion reached that the geometry was and would remain stable. Based on these evaluations, the conclusion was reached that the S/G could be operated safely and that additional repair attempts would not be made. However, during unit startup, the weld repair did not hold and at approximately 1500 psi it began leaking at an estimated 3-5 gpm. It could not be determined whether the 3-5 gpm leak path is the same leak observed during the post repair leak tests or if a new leak path developed. Subsequent to the identification of leakage in the "A" S/G the unit was cooled down. The final repair of tube R8C52 is covered in Section II.3, Special Repairs.

II.3 Special Repairs

Due to difficulties encountered in the performance of weld repairs on tube R8C52, a special repair technique was developed by CP&L and the S/G vendor and applied to this tube. The weld repair problems are attributed to the inclusion of contaminates in the weld. The source of these contaminates is assumed to be the tubesheet clad to tubesheet crevice. Additional weld repair attempts were not considered viable as the contaminated material could not be completely removed. Therefore, the repair technique applied was installation of a mechanical tube plug. The tube end was initially prepared in the same manner as for a weld repair. The remaining tube wall was then machined to accept the mechanical plug. A mechanical plug was then installed in the remaining rolled region of the tube sealing off both the inside of the tube and the tube to tubesheet interface. This eliminated all potential leak paths from R8C52.

This repair technique resulted in a small band (less than 3/16 inches wide) of carbon steel tubesheet material being exposed to primary coolant. The potential for corrosion of the carbon steel was evaluated via review of corrosion data. This evaluation performed from a primary coolant chemistry as well as tubesheet integrity standpoint revealed the following:

1. Essentially zero corrosion can be expected for high temperature conditions typical of power operations and for low temperature conditions prior to venting of the Reactor Coolant System (RCS).

II.3 Special Repairs (Continued)

2. A corrosion rate of approximately 0.1 mils per month can be expected for cold shutdown conditions when the RCS is vented. This is not considered to represent a significant problem for the next operating cycle.

3. Any affect to plant chemistry as a result of corrosion would be insignificant if detectable.

These evaluations were based on actual corrosion tests performed on carbon steel and inconel couples. CP&L and the S/G vendor believe that these tests are generally representative of the conditions in the H. B. Robinson S/G's, however, since the tests do not completely simulate the potential crevice configuration present in the S/G at the tubesheet-to-cladding interface further testing is planned to evaluate this condition for long-term consideration.

Subsequent to installation of the mechanical plug in tube R8C52, a 200 psi leak test was performed. This revealed slight leakage of approximately 5 drops per minute. This leakage was evaluated by CP&L and Westinghouse and determined not to pose an operational problem based on the observed leak rate. Therefore, the repair is considered acceptable and additional repair efforts are not planned at this time. However, this repair will be visually inspected, leak checked and re-evaluated concurrent with future inspection efforts in this S/G.

III. SUMMARY

The H. B. Robinson Unit No. 2 S/G's were subjected to a state-of-the-art eddy current inspection to detect and quantify tube wall corrosion on essentially 100% of the tubing. This inspection revealed tube degradation in several distinct regions of each S/G where degradation has been observed in the past. No new corrosion phenomonen were observed. The eddy current inspection results were evaluated to determine corrosion rates and to establish a safe operating period to maintain tube integrity under normal and accident conditions. This evaluation revealed that the S/G's can be operated for at least a 9.6 EFPM period at reduced temperature ($T_{HOT} = 560^{O}F$) and maintain tube integrity. Prior to exceeding this period, therefore, an eddy current inspection will be performed.

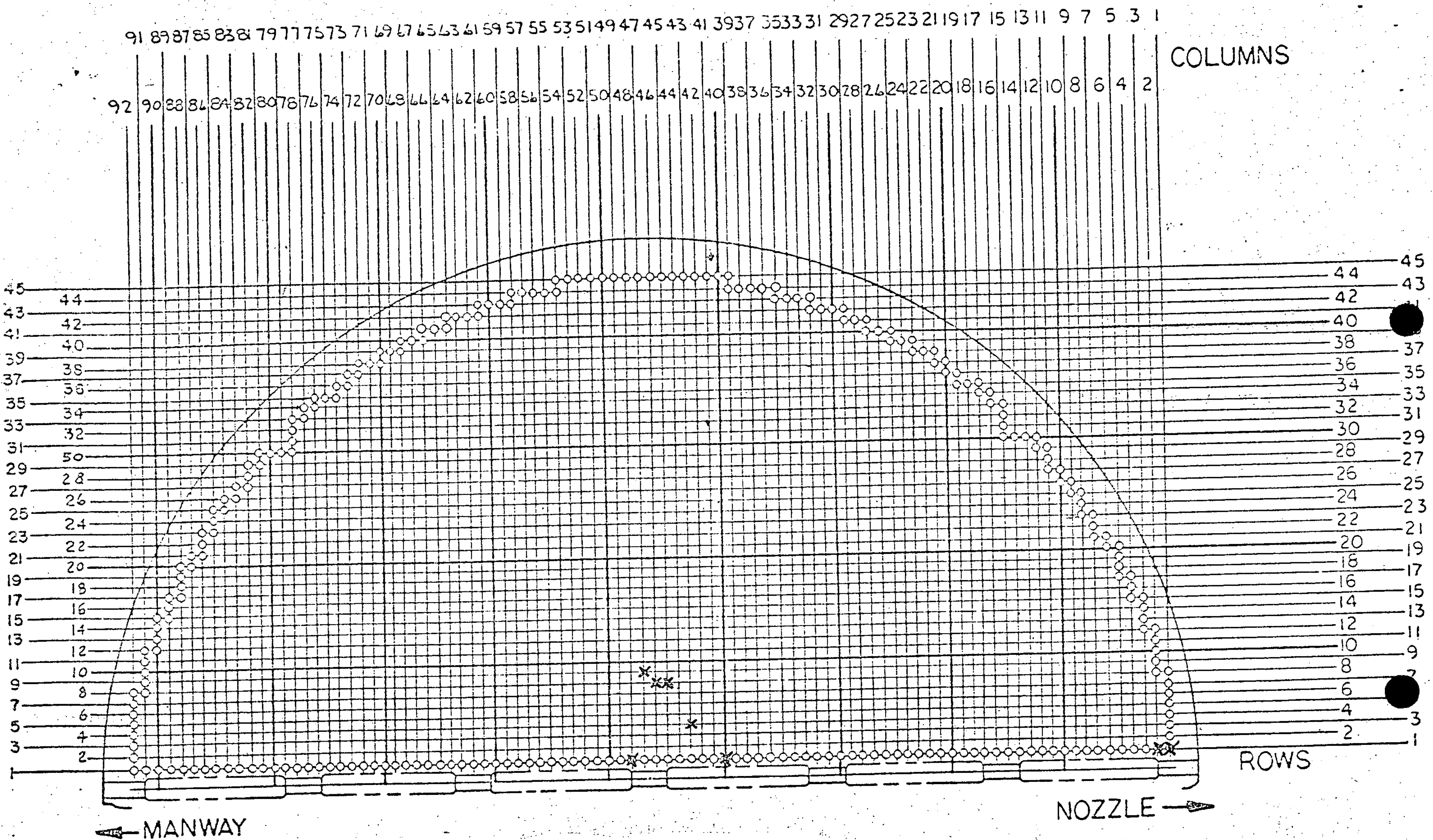
In addition, an inspection of the secondary side of "B" S/G was performed to identify any foreign objects capable of causing damage to the tube bundle. No such foreign objects were detected, nor was there any evidence of mechanical damage on the exterior of the tubes inspected.

Maintenance performed on the S/G's included mechanical plugging of tubes with eddy current indications in excess of the Technical Specification plugging limit, weld repairs, and one special mechanical plug repair. A total of 16 tubes were plugged in "A" S/G, 134 in "B" S/G, and 49 in "C" S/G.

The inspections and repairs performed will ensure that the H. B. Robinson S.E. Plant S/G's can be safely operated for 9.6 EFPM's.

FIGURE I.1.1-1

PLOT OF "B" S/G TUBES NOT INSPECTED THROUGH U-BEND



X = Denotes tubes not inspected through U-bend region.

FIGURE I.1.4-1

A S/G INLET
DISTRIBUTION OF TTS/ATS INDICATIONS

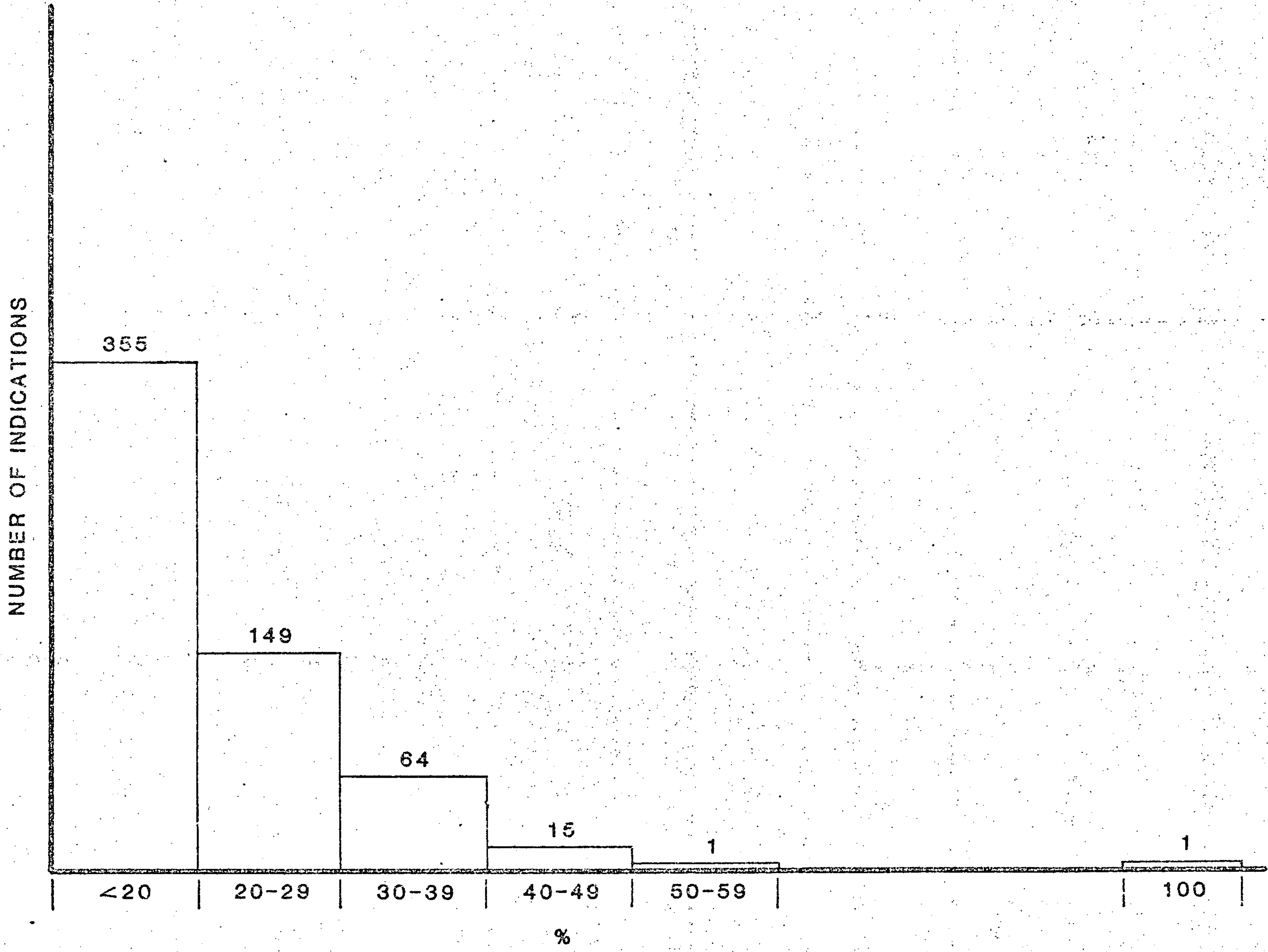


FIGURE I.1.4-2

A S/G OUTLET
DISTRIBUTION OF TTS/ATS INDICATIONS

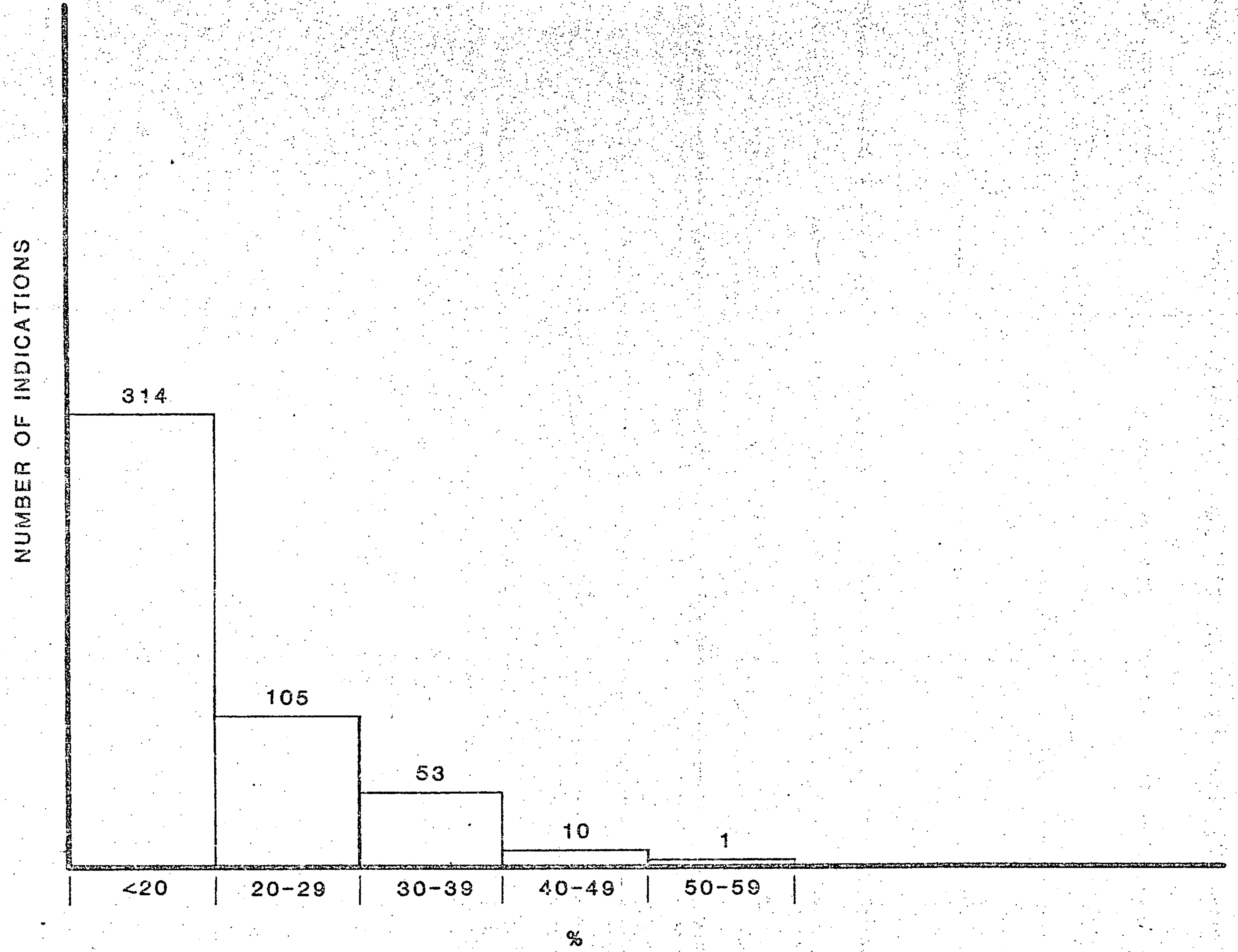


FIGURE I.1.4-3

B S/G INLET

DISTRIBUTION OF TTS/ATS INDICATIONS

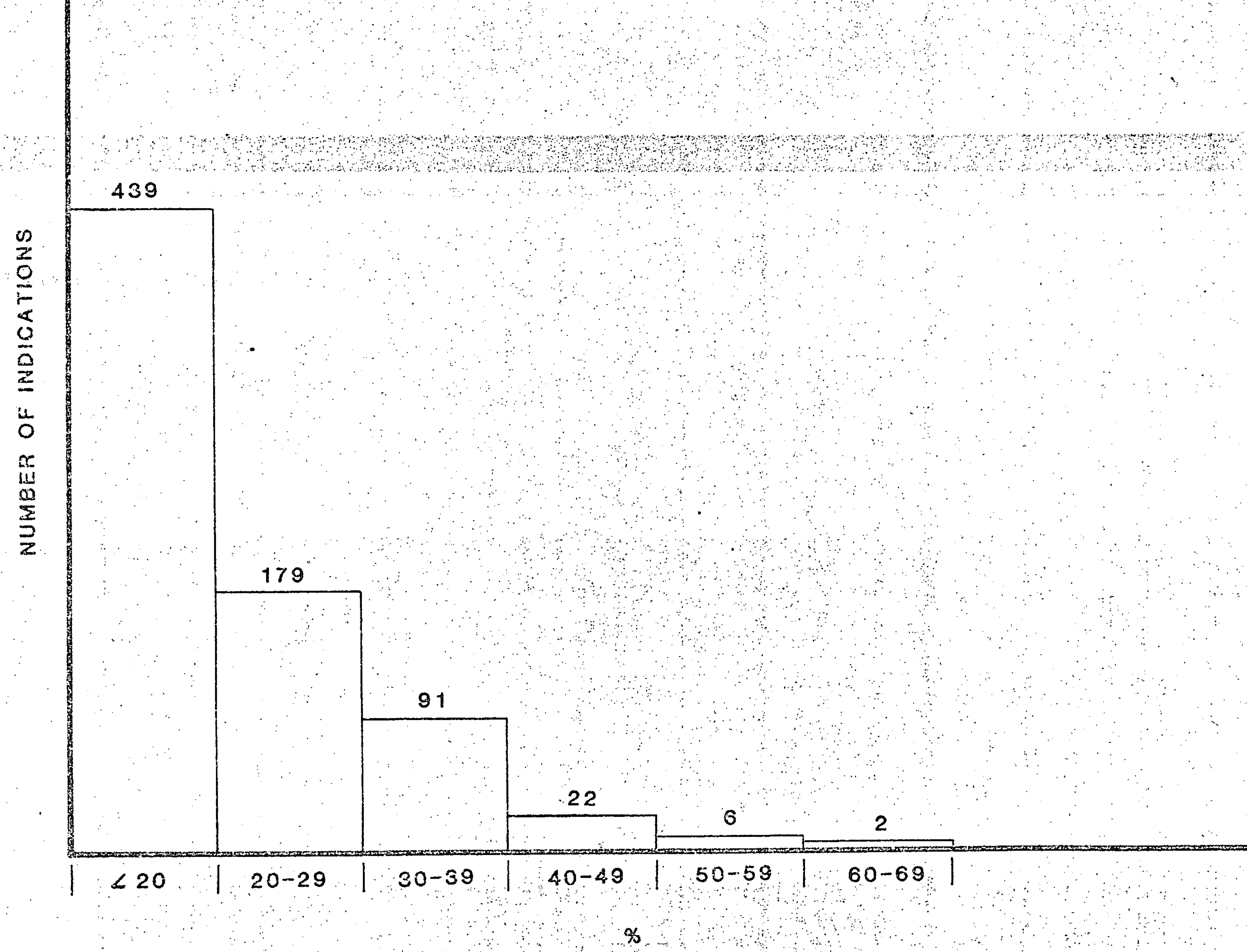


FIGURE I.1.4-4

B S/G OUTLET
DISTRIBUTION OF TTS/ATS INDICATIONS

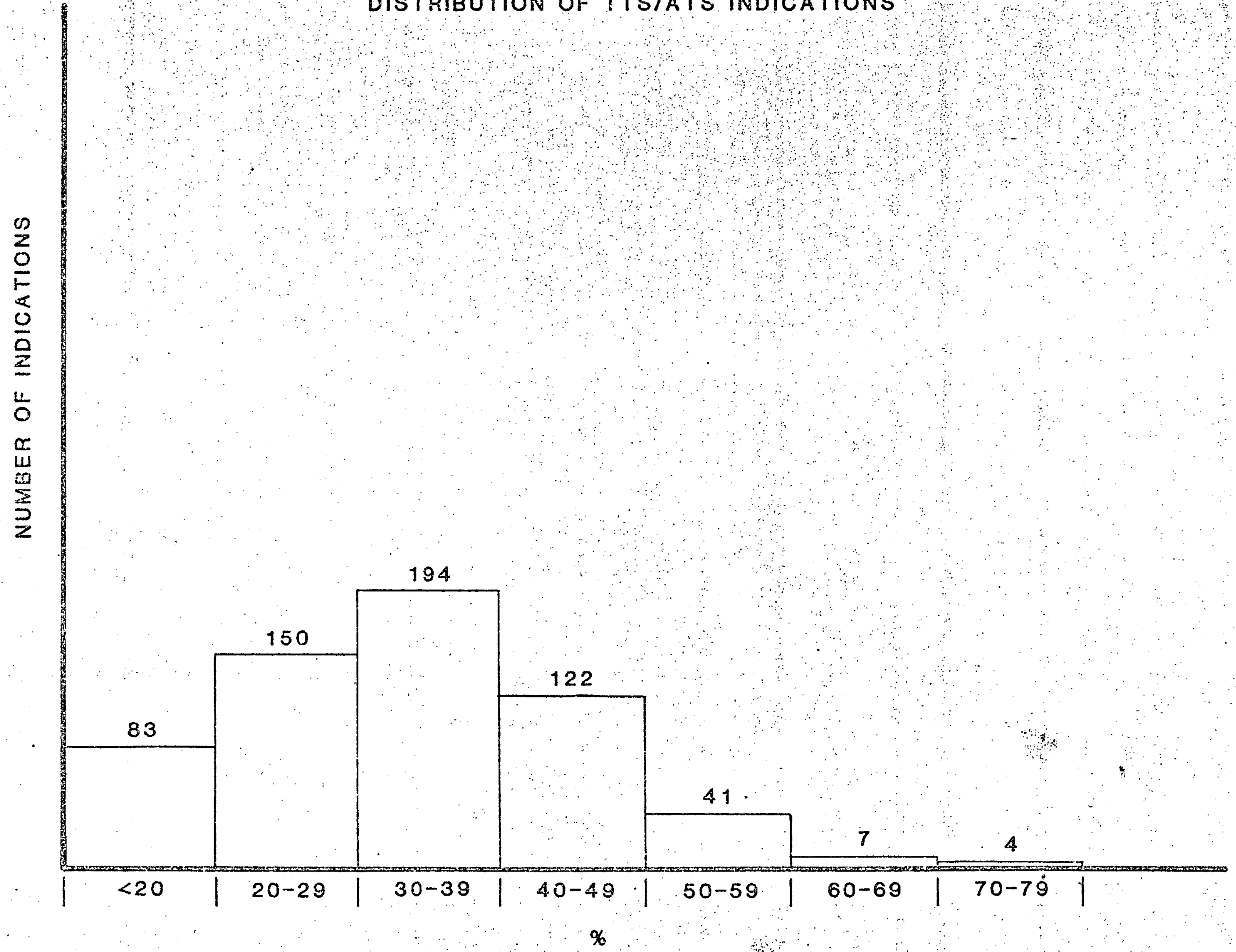


FIGURE I.1.4-5

C S/G INLET

DISTRIBUTION OF TTS/ATS INDICATIONS

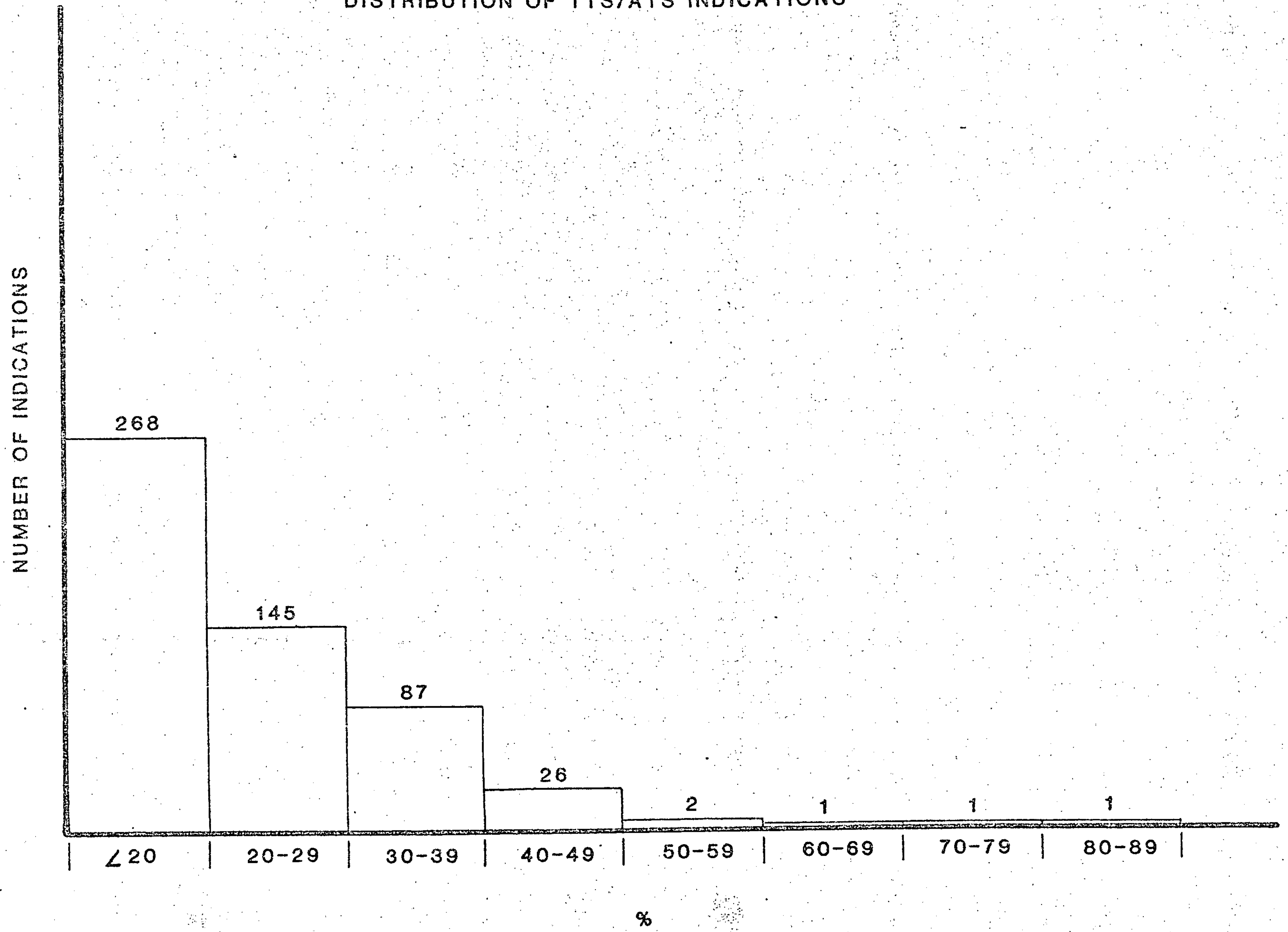


FIGURE I.1.4-6

C S/G OUTLET
DISTRIBUTION OF TTS/ATS OUTLET

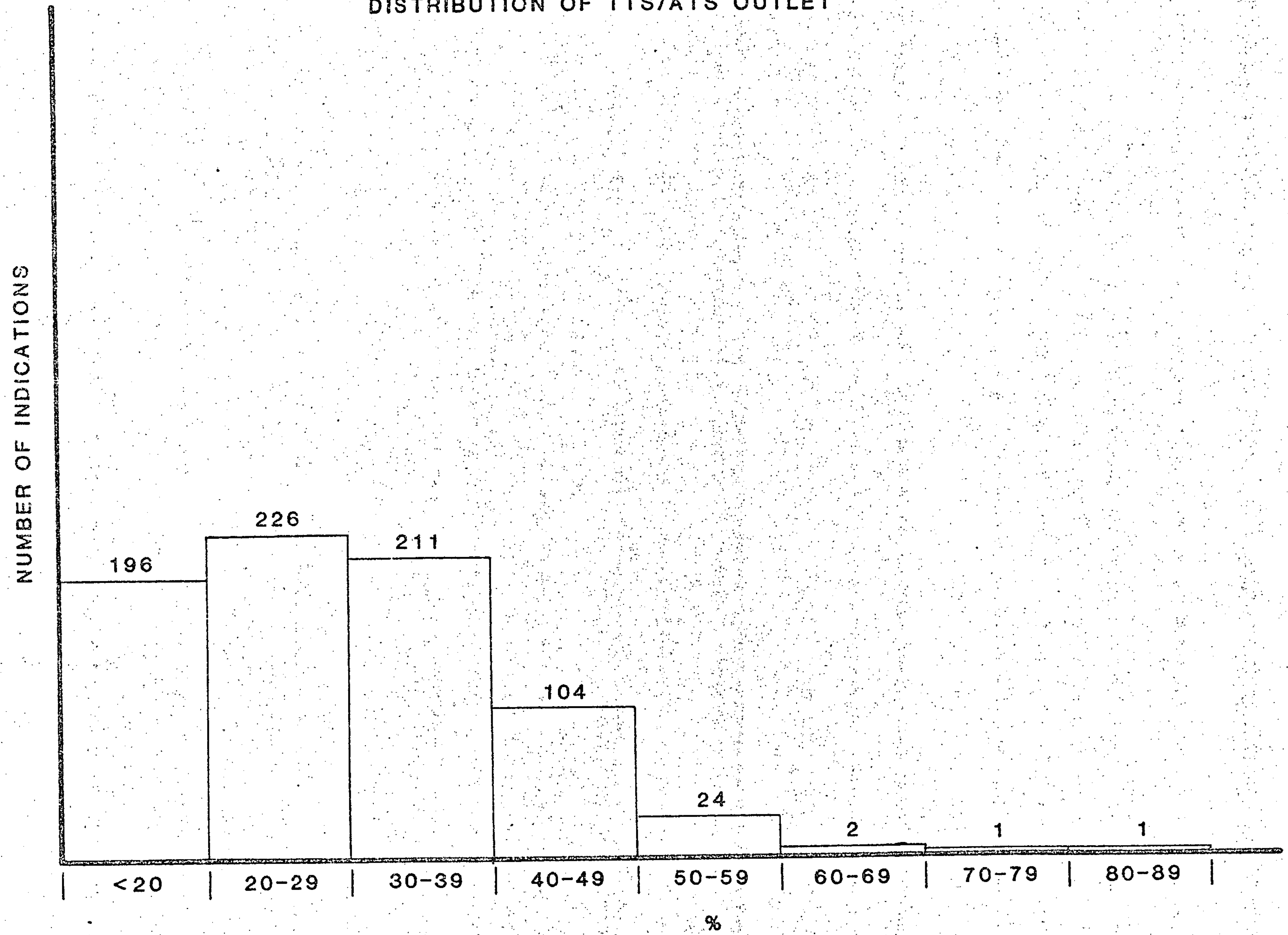


FIGURE I.1.5-1

TUBE WALL CORROSION RATES

Region	Total	No. Data Points	Rate %/EFPM*
"A" S/G Inlet TTS/ATS	-692	192	-1.14
"A" S/G Outlet TTS/ATS	-165	121	-.43
"A" S/G U-bend	-68	28	-.78
"B" S/G Inlet TTS/ATS	-50	.85	-.085
"B" S/G Outlet TTS/ATS	593	240	.78
"B" S/G U-bend	-10	12	-.025
"C" S/G Inlet TTS/ATS	257	113	.72
"C" S/G Outlet TTS/ATS	1025	285	1.14
"C" S/G U-bend	-	0	-

*Effective Full Power (2300 MWth) months.

FIGURE II.1-1

"A" S/G

HOT LEG

ROW	COLUMN	%	LOCATION	NOTES
8	16	92	10" ATE	
5	27	88	12" ATE	
6	34	87	10" ATE	
10	34	77	10" ATE	
5	35	93	16" ATE	
5	39	85	12" ATE	
16	80	68	10" ATE	
11	9	64	18" A 6 TSP	
29	18	50	24" A 6 TSP	
7	42	50	2" ATS	
42	53	77	TTS	
9	49	100	21" ATS	No significant eddy current signal change from 8/81 inspection.

COLD LEG

ROW	COLUMN	%	LOCATION	NOTES
21	68	58	7½ - 10" ATS	
5	70	Squirrel (leaker)	11" ATE	

OTHER

ROW	COLUMN	%	LOCATION	NOTES
22	69	leaker - hot leg		No defect detected by eddy current.
21	69			Plugging error.

FIGURE II.1-1

(Continued)

"B" S/G

HOT LEG

ROW	COLUMN	%	LOCATION	NOTES
1	8	79	5" ATE	
5	19	79	6" ATE	
11	21	82	9" ATE	
12	23	77/70	9" ATE/6" ATE	
33	24	86	6" ATE	
14	24	93	11" ATE	
27	25	56	11" ATE	
4	26	87	11" ATE	
20	40	94	6" ATE	
1	46	74	8" ATE	
27	29	88	10" ATE	
17	30	80	3 - 5" ATE	
6	31	82	8" ATE	
29	31	84	7 - 10" ATE	
32	31	83	8" ATE	
23	34	92	7" ATE	
25	34	85	12" ATE	
26	34	79	5" ATE	
29	34	76	12" ATE	
24	35	93	4" ATE	
31	36	87	11" ATE	

FIGURE II.1-1

(Continued)

"B" S/G

HOT LEG (Continued)

ROW	COLUMN	%	LOCATION	NOTES
23	36	94	9" ATE	
34	38	83/81	11" ATE/7" ATE	
31	38	82	4 - 9" ATE	
31	39	86	7" ATE	
23	39	83	9" and 11" ATE	
19	42	89	6" ATE	
35	44	86	6" ATE	
34	44	88	7" ATE	
21	44	98	16" ATE	
13	44	86	6" ATE	
35	46	88	9" ATE	
25	46	80	4" ATE	
14	47	93	4" ATE	
34	48	79	7" ATE	
19	49	90	7" ATE	
28	49	77	7" ATE	
22	51	89	3 - 5" ATE	
9	52	60	5" ATE	
19	53	85	8" ATE	
27	53	89	3" ATE	

FIGURE II.1-1

(Continued)

"B" S/G

HOT LEG (Continued)

ROW	COLUMN	%	LOCATION	NOTES
14	56	89	11" ATE	
16	57	83	11" ATE	
7	57	87	6" ATE	
25	59	89	9" ATE	
24	60	63	9" ATE	
32	67	86	6" ATE	
18	68	86	10" ATE	
6	69	99	8" ATE	
14	69	79	6 - 8" ATE	
6	70	80	4 - 6" ATE	
16	72	72	4 - 6" ATE	
27	42	49	TTS	
27	44	52	TTS	
34	38	51	½" ATS	Also listed in hot leg ATE
27	38	53	TTS	
20	41	54	2" ATS	
37	43	60	1" ATS	
25	43	49	TTS	
9	43	51	TTS	
3	50	65	3" ATS	
26	51	48	TTS	

FIGURE II.1-1

(Continued)

"B" S/G

HOT LEG (Continued)

ROW	COLUMN	%	LOCATION	NOTES
39	55	48	½" ATS	
43	57	83	2 TSP	

COLD LEG

ROW	COLUMN	%	LOCATION	NOTES
26	38	73/50	7"/9" ATS	
26	53	49	12" ATS	
25	55	60	10" ATS	
21	65	54	10" ATS	
17	67	54	10" ATS	
19	69	49	5" ATS	
15	71	52	10" ATS	
6	66	55	12" ATS	
8	66	60	12" ATS	
9	66	50	12" ATS	
5	65	56	10" ATS	
4	64	49	2" ATS	
9	63	55	10" ATS	
8	62	50	12" ATS	
4	60	49	4" ATS	
5	59	49	9" ATS	
8	57	48	10" ATS	
9	57	49	12" ATS	

FIGURE II.1-1

(Continued)

"B" S/G

COLD LEG (Continued)

ROW	COLUMN	%	LOCATION	NOTES
10	54	72	14" ATS	
7	53	52	8" ATS	
9	52	49	8 - 12" ATS	Also listed in H.L. ATE's
10	18	52	6" ATS	
5	20	53	2 - 5" ATS	
6	20	65	2" ATS	
5	28	55	5" ATS	
5	31	59	6" ATS	
5	32	50	6" ATS	
5	34	54	5" ATS	
6	34	52	6" ATS	
5	35	51	6" ATS	
5	36	48	4" ATS	
5	37	48	3" ATS	
5	39	76	5" ATS	
1	51	57	½" ATS	
2	51	50	2" ATS	
3	56	49	½" ATS	
2	57	57	½" ATS	
2	58	50	½" ATS	

FIGURE II.1-1

(Continued)

"B" S/G

COLD LEG (Continued)

ROW	COLUMN	%	LOCATION	NOTES
3	58	70	½" ATS	
3	59	55	½" ATS	
3	60	67	1" ATS	
3	61	49	2" ATS	
3	64	52	½" ATS	
2	32	50	2" ATS	
2	33	50	1" ATS	
3	37	63	1" ATS	
3	39	50	2" ATS	
5	68	50	3" ATS	
11	68	52	12" ATS	
12	68	70	12" ATS	
6	67	52	12" ATS	
11	67	56	12" ATS	
12	67	52	12" ATS	
13	67	55	12" ATS	
5	66	58	12" ATS	
5	30	63	5" ATS	
9	77	57	2" ATS	
7	75	52	1" ATS	

FIGURE II.1-1

(Continued)

"B" S/G

COLD LEG (Continued)

ROW	COLUMN	%	LOCATION	NOTES
14	73	52	2" ATS	
5	72	50	2" ATS	
7	70	50	8" ATS	
7	18	67	7" ATS	
12	20	50	2" ATS	
13	20	56	3" ATS	

OTHER

ROW	COLUMN	%	LOCATION	NOTES
5	38			Plugging Error
5	29			Plugging Error
31	37			Plugging Error
11	18			*Plugging Error
22	49			*Plugging Error
27	49			*Plugging Error
24	49			*Plugging Error

*Correction of previous plugging errors.

FIGURE II.1-1

(Continued)

"C" S/G

HOT LEG

ROW	COLUMN	%	LOCATION	NOTES
14	22	80	8" ATE	
3	23	80	4" ATE	
24	25	82	4" ATE	
20	26	94	4" ATE	
4	30	41	10" ATE	
24	32	85	4" ATE	
15	33	90	8" ATE	
7	36	77	5" ATE	
26	22	83	2" ATS	
30	21	77	½" ATS	
30	25	59	4" ATS	
36	28	56	½" ATS	
8	47	65	TTS	

COLD LEG

ROW	COLUMN	%	LOCATION	NOTES
12	60	53	13" ATS	
9	61	52	10" ATS	
10	61	55	6" ATS	
14	61	55	8" ATS	
11	63	55	6 - 12" ATS	

FIGURE II.1-1

(Continued)

"C" S/G

COLD LEG (Continued)

ROW	COLUMN	%	LOCATION	NOTES
11	68	52	8" ATS	
2	70	52	2" ATS	
3	75	51	3" ATS	
3	77	49	3" ATS	
3	78	48	3" ATS	
7	19	51	½" ATS	
8	19	53	½" ATS	
9	19	86	½" ATS	
16	19	61	½" ATS	
4	21	50	½" ATS	
11	21	49	TTS - 7½" ATS	
14	21	52	½" ATS	
10	23	49	4 - 8" ATS	
11	23	51	4 - 8" ATS	
12	23	55	4 - 8" ATS	
6	24	52	7" ATS	
10	24	52	8" ATS	
12	25	70	5 - 8" ATS	
15	25	50	5 - 10" ATS	
11	26	51	7½ - 12" ATS	

FIGURE II.1-1

(Continued)

"C" S/G

COLD LEG (Continued)

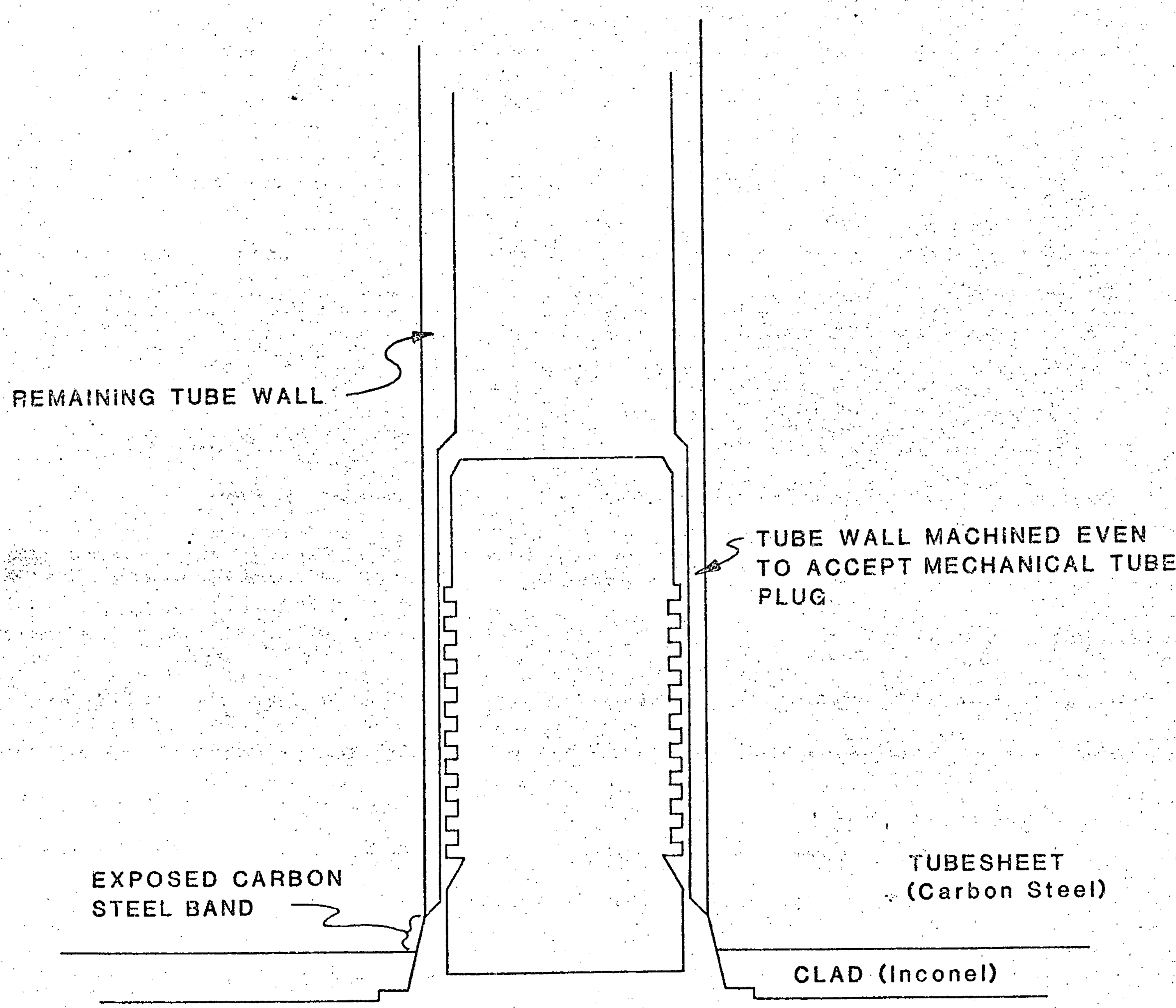
ROW	COLUMN	%	LOCATION	NOTES
12	26	57	7 - 12" ATS	
15	26	59	5 - 15" ATS	
2	29	52	1" ATS	
29	40	50	2" ATS	
7	49	49	10" ATS	
7	51	49	10" ATS	
6	53	69	6" ATS	
8	53	51	10" ATS	
7	54	54	10" ATS	

OTHER

ROW	COLUMN	%	LOCATION	NOTES
9	29			Obstructed tube
4	30	41	10" ATS	Plugged for unit reliability

FIGURE II.3-1

TUBE / TUBESHEET COUNTERBORE CONFIGURATION FOR MECHANICAL PLUG REPAIR



ATTACHMENT 1

WESTINGHOUSE RECOMMENDATION FOR REALISTIC EVALUATION OF DEPTHS OF TUBE WASTAGE AT H. B. ROBINSON

SUMMARY

This report discusses the evaluation of steam generator tube wastage indications at the H. B. Robinson Plant. It had been our experience that the eddy current (E/C) technique tends to overestimate the depth of such penetrations. Furthermore, the uncertainty in the EC data when dealing with such indications is less than 9% since the basis of this number is the ASME standard, which uses signal amplitudes much smaller than those expected for wastage type penetrations. Considering all the available data, it is concluded that the 9% conversatism used in estimating the margin for corrosion can be discounted when evaluating wastage type penetrations.

Field Data on Tubes Pulled From Operating Plants

The data derived from the examination of tubes pulled from operating plants during several years shows that the eddy current technique, using the ASME calibration standard, yields overestimates of penetration depth when wastage type penetrations are involved. Figure 1 compares the depths measured by metallugraphic method with the estimated depths by EC data for steam generator tube exhibiting wastage type penetrations. These tubes were pulled from several plants. The eddy current estimates for penetrations in the range of ± 20% should be ignored since the confidence level here is very low. Excluding the ± 20% signals, the data shows an overestimate of about 10 to 15% in the indicated signal range of 30 to 60% penetration. The experimental

work performed at various laboratories to investigate the evaluation of wastage type penetrations fully support this field experience. The error results from the use of ASME drilled hole standard for calibration of EC data. Wastage penetrations do not resemble drilled holes and generally involve larger areas of the tube than the drilled hole. The influence of the larger surface area involvement results in higher depth estimates by EC data than the actual depths measured by metallugraphy.

Uncertainty in Eddy Current Estimates

The often quoted uncertainty of ± 9% of the depth estimates for eddy current data is based on the use of the ASME drilled hole standard. The standard consists of flat-bottom holes of different depths. The diameters of the holes are adjusted such that the amplitudes of the EC signals from these different depth holes are approximately equal. For instance, the diameter of the 40% hole is 3/16" while those for 60% and 80% are 7/64" and 5/64" respectively. The volumes of these machined holes is quite small compared with the volumes involving wastage type penetrations of comparable depth and thus the amplitude of signals expected from wastage type penetrations of approximately ± 40% would be much larger than the amplitude of the signals from the drilled hole ASME standard. Thus, the uncertainty of ± 9% in EC data becomes a factor when wastage type penetrations of approximately ± 40% are involved. Furthermore, there is a built-in conservatism for the evaluation of wastage type penetrations if one uses the ASME standard for calibration. This observation has a theoretical basis and is supported by

ATTACHMENT 1

(Continued)

both laboratory data and actual plant data on pulled tubes. The signal phase angle is not only a function of the depth, it is also a function of the area of the flaw. The phase angle is a monotonically proportional function of the area of the flaw at constant depth. The experimental data for the case of 100% through holes of different diameters is shown in Figure 2. If the area of the flaw is larger than the area of the same depth hole of the ASME standard, the flaw would yield a larger phase angle than the standard hole of same depth. This results in an overestimate of the depth of penetration of the large area flaws. The data of Figure 2 shows the affect of phase dependence on flaw area if the diameter of the hole is larger than of the ASME standard, the precise use of a calibration based on the standard becomes unrealistic since it results in an estimate the depth of penetration of over 100%. These observations are further supported by the experimental work on machined flaws of different geometries performed at different laboratories.

Experimental Data on Machined Flaws Simulating Wastage

Figure 3 shows the signal phase angle vs. actual depth of penetration for various wastage type machined flaws along with the data on the ASME drilled hole calibration standard. These data indicate a consistent overestimate of depth on the basis of the ASME calibration standard. The results of the work done at Battelle Institute is shown in Figure 4. Here the actual depths are plotted against the depths estimated from the phase of the EC signals - again on the basis of calibration using the ASME standards. The geometry of the machined flaws simulated elliptical type wastage and the "compound wastage"

consisting of about 180 degrees band of uniform wastage followed by tapered type wastage. The data again shows significant overestimates of depths by EC technique when estimating wastage type penetrations.

The above observations are valid for data taken at single frequency. If one uses the technique of mixing data taken at two frequencies the results are more complicated. For example, when the 400 kHz and 100 kHz data are mixed to cancel the interfering signals from support plates or Anti-Vibration Bars (AVB's) for estimating the depths of large area wear type penetrations resulting from vibrations or fretting, interpretation of the results is more complicated. Figure 5 shows laboratory data taken on wear type flaws at AVB locations. The data shows a cross-over near 60% wall penetration. The phenomenon of cross-over shown in Figure 5 is not relevant to the case where only 400 kHz data is used for depth estimation.

In Summary, because of:

1. The large uncertainty in using the $\pm$ 9% error band for interpreting data, using the ASME standard is not valid in those cases of wastage flaws where penetrations of approximately $\pm$ 40% are present.
2. The evidence of significant overestimation of penetrations due to wastage by EC procedures used in the field at this time as shown in Figure 1.

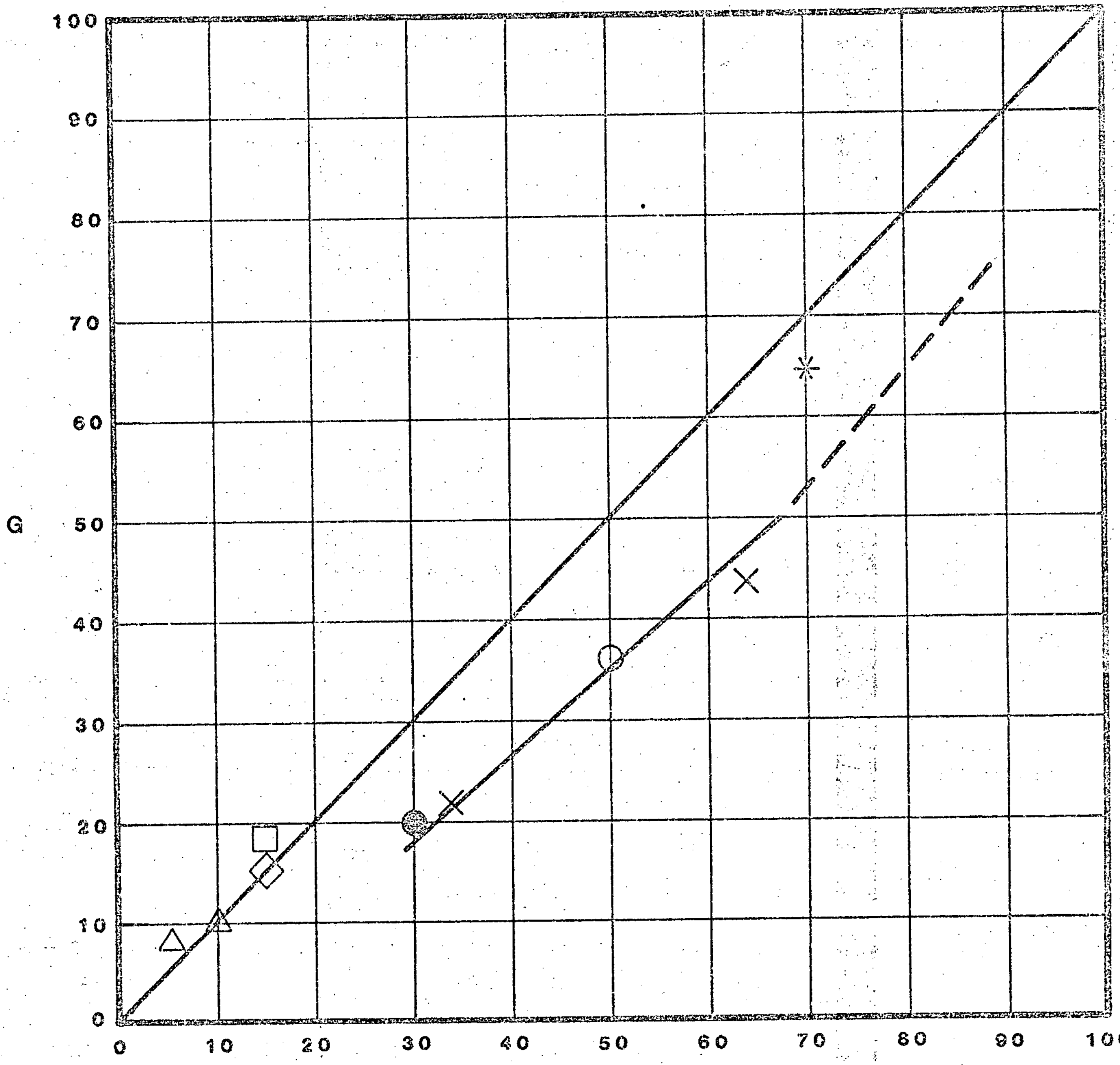
ATTACHMENT 1

(Continued)

3. The laboratory data on wastage type flaws showing overestimates of penetrations when using ASME standards for calibration.

It is recommended that the 9% conversatism factored into estimations of the margin for tube corrosion be elimated when tube wastage is involved.

SUMMARY OF ACTUAL MEASUREMENTS OF WALL - THINNED STEAM GENERATOR TUBES FROM OPERATING PLANTS



✕ = Plant G Tube A 19-23 (Two Indications)

○ = Plant E Tube A 59-36 ● A 61-36

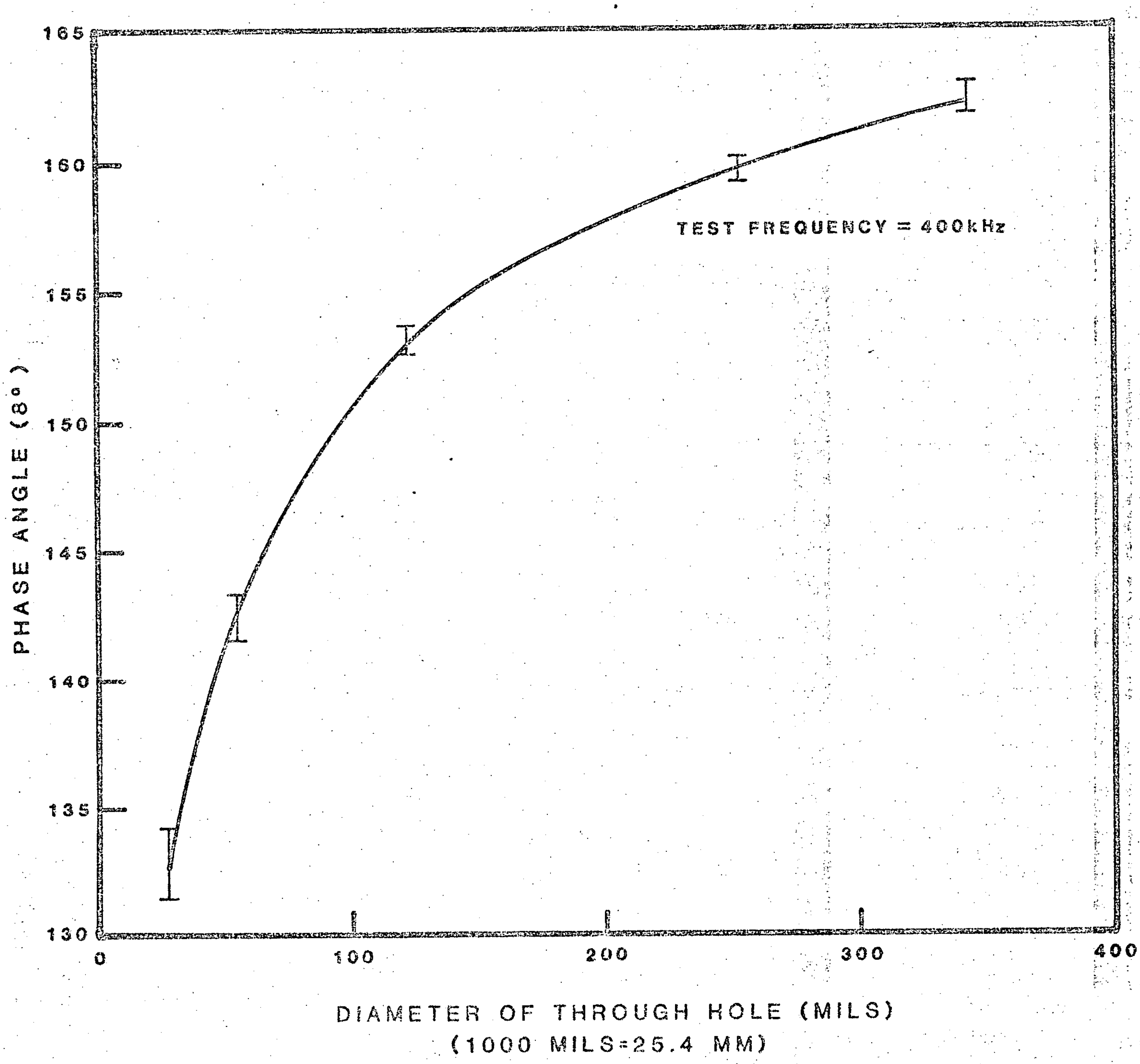
△ = Plant B Tube B 17-47 ▲ B 17-46

□ = Plant P Tube B 15-46

◇ = Plant C Tube A 11-52

✳ = Battelle Columbus Report, July 11, 1974

FIGURE 1



165
160
155
150
145
140
135
130
PHASE ANGLE (θ°)
TEST FREQUENCY = 400kHz
0
100
200
300
400
DIAMETER OF THROUGH HOLE (MILS)
(1000 MILS=25.4 MM)

FIGURE 2

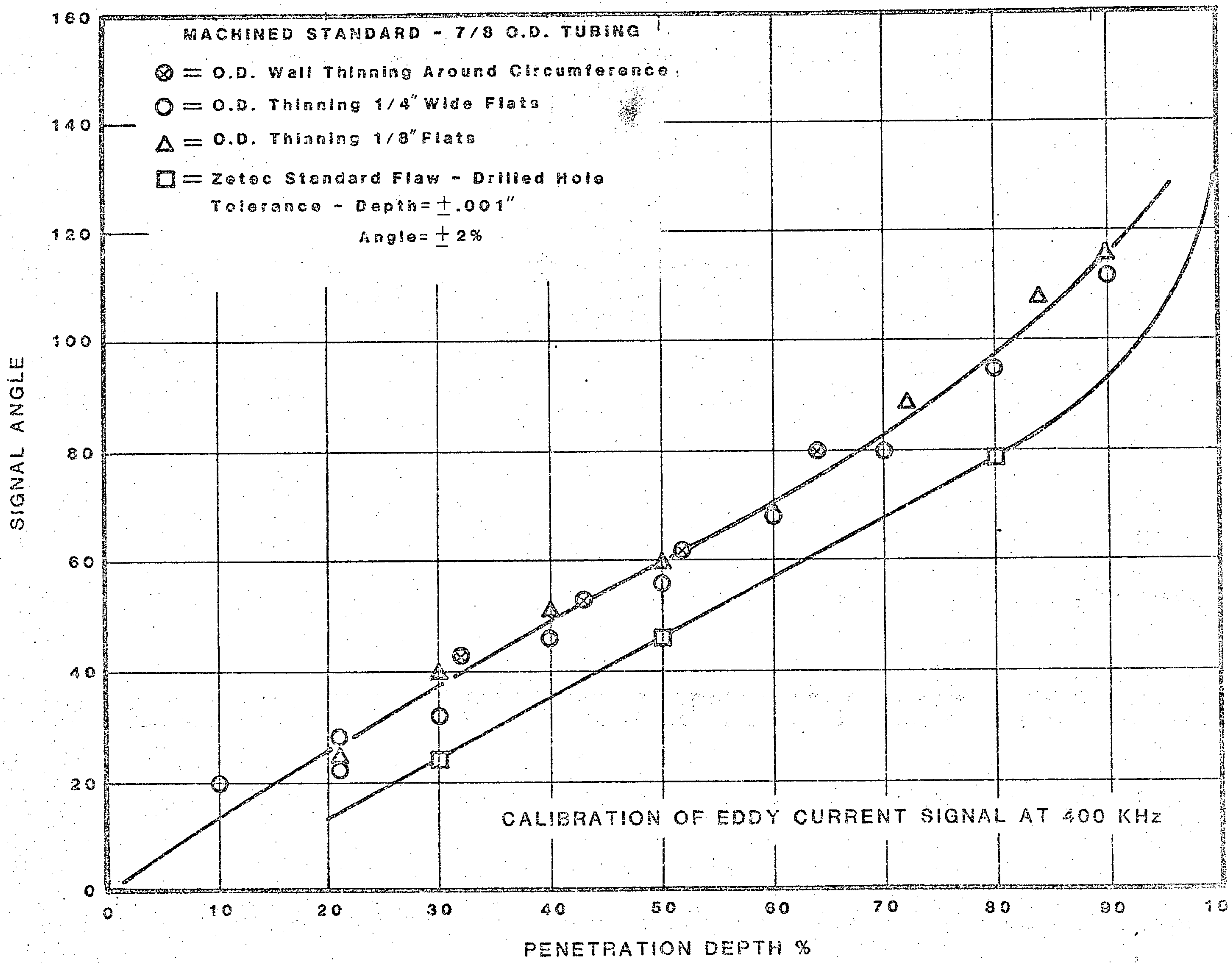
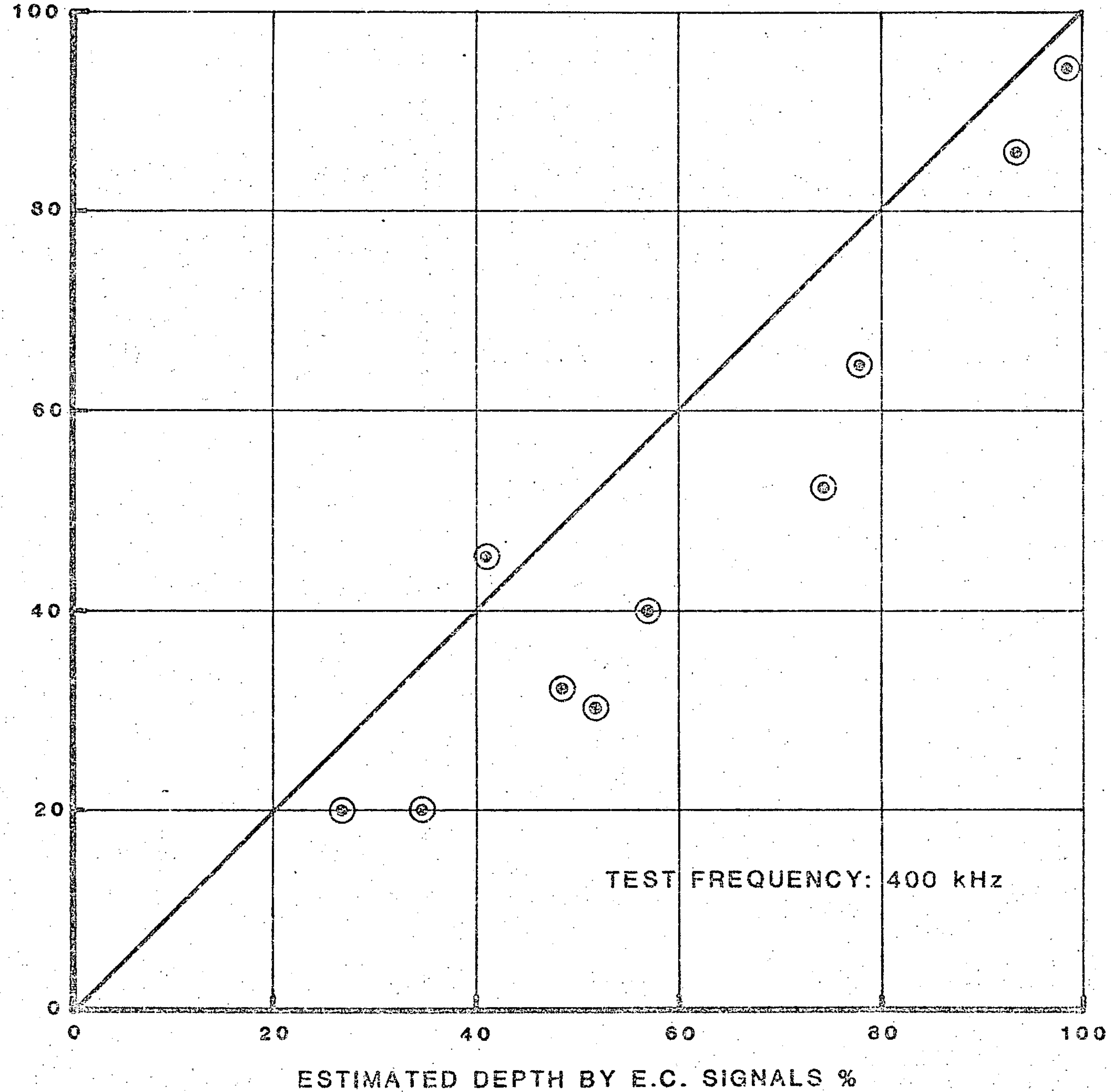

MACHINED STANDARD - 7/8 O.D. TUBING
⊗ = O.D. Wall Thinning Around Circumference
○ = O.D. Thinning 1/4" Wide Flats
△ = O.D. Thinning 1/8" Flats
□ = Zetec Standard Flaw - Drilled Hole
Tolerance - Depth = ±.001"
Angle = ±2%
SIGNAL ANGLE
160
140
120
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100
CALIBRATION OF EDDY CURRENT SIGNAL AT 400 KHz
PENETRATION DEPTH %

FIGURE 3

COMPARISON OF DEPTH ESTIMATES BY E.C. TECHNIQUE AND THE ACTUAL DEPTHS OF MACHINED WASTAGE TYPE PENETRATIONS

Ref: BNL-NU REG-50512-R Sept. 30, 1976 - S. BROWN



CALIBRATION CURVE BASED ON PHASE ANGLES FOR THE AVB TYPE FLAWS

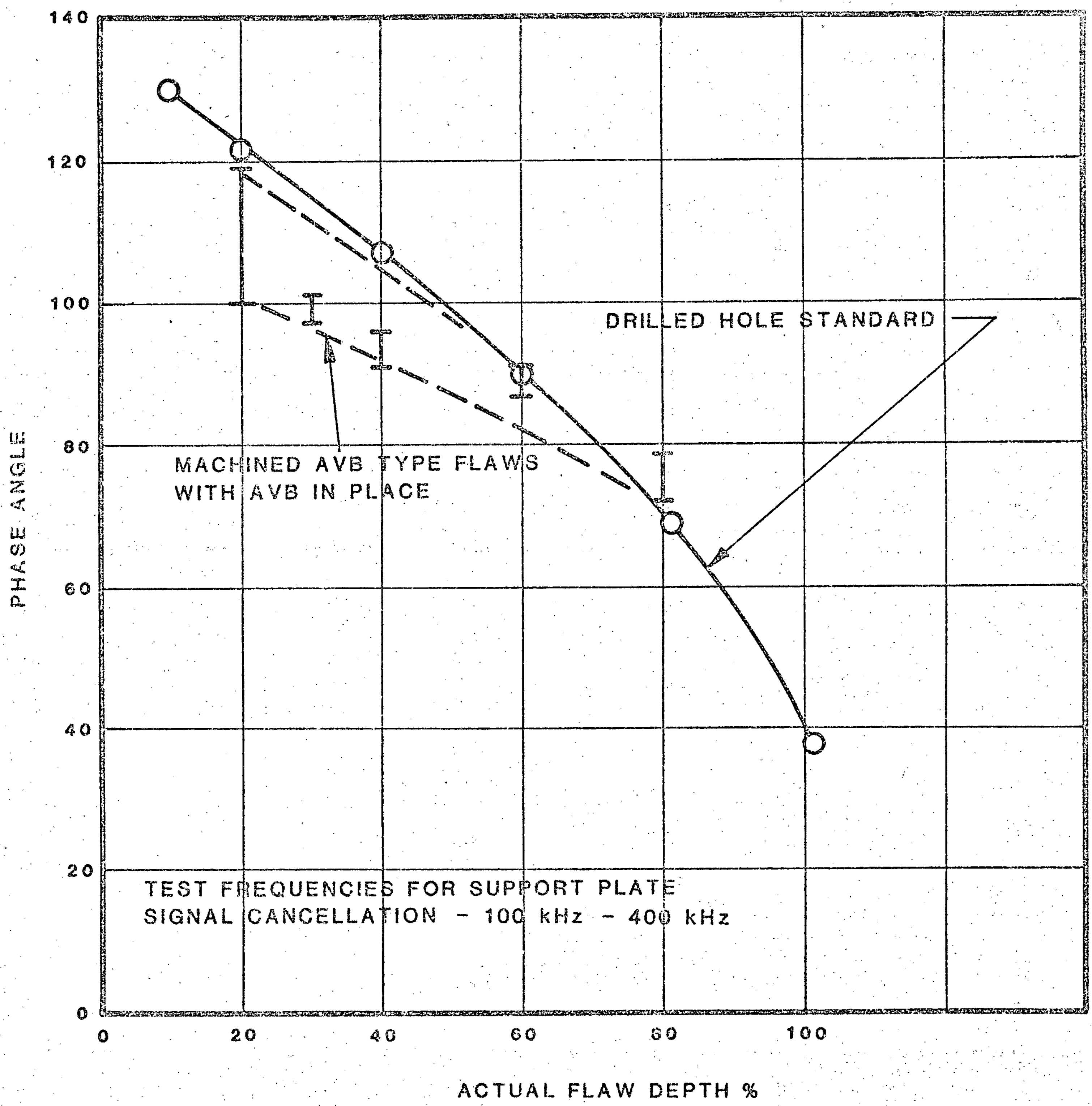


FIGURE 5