Turkey Point 4 Steam Generator
Inspection Program

I. Introduction

An extensive inspection program for the Turkey Point Unit 4 steam generators was conducted in April, 1979. The following items were accomplished:

1. gauging of steam generator hot leg and cold leg tubing - all steam generators
2. measurements of visible flow slots in all steam generators
3. annulus measurements of steam generator B
4. eddy current inspection of small radius U-bends in steam generator A
5. Regulatory Guide 1.83 eddy current measurements in the hot legs and cold legs of all steam generators
6. preventive plugging.

Table 1 is a summary of the approximate number of steam generator tubes inspected in each category and in each steam generator.

Table 1: Summary of Total Steam Generator Tubes Inspected

	A Hot Leg	A Cold Leg	B Hot Leg	B Cold Leg	C Hot Leg	C Cold Le
Gauging	1293	250	1189	191	1295	239
U-Bend Rows 2-5	-	139	-	-	-	-
R.G. 1.83	147	350	166	148	146	156

This report summarizes the inspections conducted, the results of those inspections, and preventive plugging programs accomplished.

II. Inspection Programs

A. Gauging Program

The tube gauging program in the tubelane area is based on expected regions of high tube deformation. These regions are determined by previous inspection experience and by the finite element analysis which, when combined with tube strain tests, yields tube hoop strains versus tube location and extent of plate deformation. Initially, the 12.5% strain boundary was used in the gauging program when little plant specific data was available. After two initial inspections and four reinspections of the Turkey Point plants, we now have the benefit of plant specific information which indicates the conservatism of the 12.5% boundary and the adequacy of the 15% boundary. This is, the majority of the tubes inspected do not restrict the .650 inch probe. In addition, all tubes restricting the .610 inch or .540 inch probe have all fallen well within the inspection boundary. This is significant since the .610 inch and the .540 inch restricted tubes form the basis for the plugging patterns in the tubelane region.

Full closure was observed in Turkey Point 4 steam generators during the May 1977 inspection. Turkey Point 4 is regarded as beyond full closure by approximately 15.5 EFPM's. The tube hoop strain contours estimated for 15.5 EFPM's beyond full closure were utilized to determine the 15% boundary for the inspection in the tubelane region. Additional inspection programs were defined for the periphery, wedge, and patch plate regions. These programs were based on previous leaker histories at the Turkey Point and Surry sites, as well as previous gauging results at those sites, as deemed appropriate. Due to the current awareness of the potential for tube deformation on the cold leg side, inspections of all three steam generator cold legs were performed.

The gauging inspection boundaries for the April 1979 inspection are indicated in Figure 1 (typical hot leg) and Figure 2 (typical cold leg). Additionally, if a restricted tube was found close to the inspection boundary, the inspection was expanded in that area.

B. Other Denting Related Inspections

The U-bends of unplugged tubes in rows 2 thru 5 in steam generator A were examined with 100 KHZ. These inspections are performed to confirm the integrity of the small radius U-bends in low number rows. In addition, annulus measurements were taken in steam generator B. These measurements provide a qualitative indicator of the upper plate expansion trends in the most affected steam generator. This is the fourth such measurement of this type for steam generator B. Visible flow slots were photographed in all three steam generators.

C. Regulatory Guide 1.83 (R.G. 1.83) Inspection

The types and extent of inspections required in this area are specified in R.G. 1.83. Typical inspection plans for the hot leg and cold leg regions are included in this report (Figures 3 and 4).

III. Inspection Results

A. Gauging Programs

Results of the gauging inspections are indicated in Figure 5, 6, 7, 8, 9, and 10, and are summarized in Table 2.

Table 2: Tube Restriction Summary

	Tubelane		Periphery and Wedge	
	Hot Leg	Cold Leg	Hot Leg	Cold Leg
SG A				
.650"	64	-	2	-
.610"	22	0	5	0
.540"	2	1	0	0
SG B				
.650"	59	-	8	-
.610"	14	4	4	3
.540"	0	0	0	0
SG C				
.650"	82	-	15	-
.610"	14	1	2	0
.540"	0	0	0	0

Summary comments resulting from the review of this and other data are as follows:

1. No leaking tubes were identified during the previous operating period.
2. Tubes in the tubelane region that restrict the 0.650 inch probe or less lie within the 15% strain boundary.
3. Tubes in the tubelane region restricting a 0.540" probe (hot leg and cold leg) were adjacent to hard spots and were in Row 4 or below.
4. Restricted tubes developed adjacent to previous activity. Areas of activity were consistent with past historical data for this and other plants. Areas of note were rows 1-15 and 77-92 near the flow slots which finite element analysis predicts should progress much more rapidly than other flow slot areas. The wedge and tubelane interaction is apparently causing the finite element analysis to over predict this reaction since the activity in this area is consistent with the remainder of the tubelane flow slots. It is intended that in future inspections, this area will be plugged under the same criteria as the rest of the tubelane area.

5. Tube restrictions were noted in the inspected hot leg wedge areas of all steam generators and this activity appears consistent with previous experience at this and other units.

6. Relatively few tube restrictions were noted in the cold leg tubelane region as compared to the hot leg. Activity was noted in one of the cold leg wedge areas inspected (steam generator B) and this activity is consistent with activity noted in previous Turkey Point inspections. The overall level of activity indicates that the activity grows at a very slow rate as compared to the hot leg.

B. Other Denting Related Inspections

The U-bends of unplugged tubes in Rows 2 thru 5 in steam generator A were examined at 100 KHZ. No indications were noted in these small radius U-bends.

Annulus measurements were recorded in steam generator B. This was the fourth such measurement, and allowing for the accuracy of the equipment, no obvious trends were noted. This technique is intended to monitor for large deviations from anticipated behavior, and in this light none were noted.

The results of the flow slot measurements are indicated in Figure 11. Only the first (lower) tube support plate flow slots were all visible in each steam generator. The plots indicate that plate expansion is proceeding consistently with previous behavior.

C. Regulatory Guide 1.83 Inspection Results

R.G. 1.83 inspections were conducted in the hot leg and cold leg of all three steam generators. Extensions of these inspections were accomplished in steam generators A and B. As a result of these inspections six tubes were preventively plugged in steam generator A and no tubes were plugged in steam generators B and C.

IV. Plugging Criteria

A. Gauging Program

The progression of strain contours over the intended operating period is utilized as the basis for preventive plugging of tubes in the tubelane region which are located in rows beyond 0.540" restricted tubes. In earlier inspections the closeness of the strain contour lines prevented identification of the appropriate contour which most reasonably indicated the extent and progression of tubes with greatest deformation. Initially, the 15% strain contour was chosen when limited plant specific data was available and the strain contour lines indicated by finite element analysis fell close together on the plots. A review of the relationship between the most restricted tubes at Turkey Point Units 3 and 4 and the finite element analysis strain contours indicates that the 17.5% strain contour conservatively estimates the boundary of these restricted tubes.

The growth of this contour was evaluated and a conservative rate of growth for a ten month operating period was determined, that is, three rows should be plugged over most of the tubelane and up to six rows at the outside columns. Again, it should be pointed out that there have been numerous cases of tubes restricting the 0.540 inch probe for some time and not leaking.

The criterion established for plugging tubes in the region of the patch-plate differs from that used for other regions of the bundle. All leaks in the patch-plate region have occurred at the perimeter of the plate or near to the patch-plate boundary, where plug welds connect the patch-plate to the main body of the bundle. All observed data still indicate that the phenomenon at the patch-plate is local in nature and should not be attributed to the general strained state of the plate, nor can the phenomenon be represented by the finite element model. While the hoop strains in this region do not appear high enough in themselves to cause severe tube deformation, they apparently are high enough to act as catalysts for the local phenomenon which occurs at the patch-plate. Due to these factors, the region of the patch-plate has its own inspection program and a corresponding plugging criteria. Leakers, tubes that restrict the 0.540 inch

probe, and the surrounding tubes about both should be plugged. In addition, tubes that restrict the 0.610 inch probe should be plugged and tubes on either side of the patch-plate boundary (plate perimeter on one side the plug welds on the other three sides) that restrict the 0.650 inch probe should be plugged.

Finally, due to the local plate cracking that is believed to occur at the periphery and near wedge locations, tube leaks may occur here at lower levels of tube restriction than in the tubelane. Thus, the wedge areas should have their own inspection program and plugging criteria. The plugging criteria at hot leg wedge locations calls for treating leakers and tubes that restrict the 0.540 inch probe in a similar manner. In addition, tubes that restrict the 0.610 inch probe and peripheral tubes that restrict the 0.650 inch probe should be plugged. Cold leg plugging will be based on the degree of activity noted and rates of progression observed from gauging.

In reviewing the proposed 10 month operating period, it was deemed appropriate that more preventive plugging be accomplished in addition to plugging beyond .540" restricted tubes, as is currently the practice. Therefore, another basis was needed and it was determined that this basis should rely on plant specific information rather than finite element analysis results. The basis of the evaluation was the comparison of the .650" restricted tubes remaining unplugged from the previous two inspections and the gauging results on these tubes during the next inspection. The resulting sample numbered 177 tubes. To generate a conservative prediction of behavior, tubes in this sample which currently restricted only a .650" probe were assumed to have reduced in size 40 mils (.650-.610). Tubes in this sample which now restricted a .610 inch probe were assumed to have reduced in size 110 mils (.650-.540). Tubes now restricting a .540" probe were assumed to have reduced by 150 mils, which is considered to be a conservatively high estimate. The average and conservative estimate of these reductions is calculated to be approximately 100 mils for 10 months. Thus, it is conservative to assume that in 10 months, many of the currently .650" restricted tubes could reach a restriction of .540" or less.

In applying these results, engineering judgement was exercised to choose .650" restricted tubes most likely to reach .540". In general, tubes restricting a .650" probe located in plugging valleys and those in close proximity to .610" and .540" restricted tubes were considered for plugging.

The plugging criteria which supports at least ten months of operation are:

1. All tubes which do not pass the 0.540 inch probe will be plugged.

2. Additionally, for in excess of ten (10) months operation, three (3) tubes beyond (i.e., higher row numbers) any tube in columns 14 to 79 which did not pass the 0.540 inch probe will be plugged; for such tubes in columns 1 to 13 and 80 to 92 near the tubelane, a maximum of six (6) tubes and a minimum of three (3) tubes (at the edges of the flow slot) beyond any tube which would not pass a 0.540 inch probe will be plugged.

3. All tubes which do not pass the 0.610 inch probe will be plugged.

4. The tubes in any column for which plugging under criteria (1), (2), or (3) above is implemented in the tubelane region will also be plugged in the lower row numbered tubes back to the tubelane if not already plugged.

5. As a conservative measure, tubes completely surrounding any known leaking tubes including the diagonally next tube will be plugged if not already covered by the foregoing criteria.

6. In any given column which is surrounded by columns containing tubes with significant tube restrictions or prior plugging, (thereby creating a "plugging valley" in the pattern) engineering judgement will be used to fill the bottom of the valley. In the peripheral tubelane areas near the three and nine o'clock wedges, tubes surrounded by previously plugged tubes or tubes exhibiting high deformation activity will be plugged based on engineering judgement. Particular attention was paid to .650" restricted tubes relative to the ten month operating period.

7. Additional preventive plugging will be implemented at the hot leg wedge locations. This plugging will include all tubes that:

a. restrict the 0.540 inch probe
b. restrict the 0.610 inch probe
c. restrict the 0.650 inch probe at the periphery
d. surround leakers and tubes that restrict the 0.540 inch probe including the diagonally next tube.

8. Application of the criteria specified in 7 above will be made on the basis of engineering judgement for cold leg wedge locations.

9. Additional preventive plugging will be implemented in the patch-plate region. This plugging will include all tubes that:

a. restrict the 0.540 inch probe
b. restrict the 0.610 inch probe
c. surround leakers and tubes that restrict the 0.540 inch probe including the diagonally next tube
d. lie on either sides of the patch-plate boundary (plate perimeter on one side the plug welds on the other three) and restrict the 0.650 inch probe.

The ten month operating period was also evaluated relative to a postulated main steam line break accident (MSLB). In doing this, the finite element analysis plots for 18 and 24 EFPM beyond closure (Figures 12 and 13) were considered. These are considered to be representative of the anticipated advanced conditions of the Turkey Point Unit 3 steam generators over the next ten month operating period. It was assumed that the actual boundary of the 17.5% tube hoop strain contour in the most advanced steam generator (B) is indicated in the tubelane region by the previous plugging boundary and the present .540" restricted tubes. Using the finite element analysis results above, the advancement of the 17.5% tube hoop strain contour over the next ten months was estimated to be 1.9 rows. Using the fact that there are 92 tubes in a row, the total predicted tubes in the tubelane region lying within the 17.5% strain contour at the end of the next ten months is:

1.9 rows in ten months x 92 tubes per row = 175 tubes

Subtracting out the tubes that were preventively plug in this area in steam generator B this time (26) results in a total of 149 unplugged tubes within the 17.5% strain contour at the end of the ten month operating period. Assuming one intersection involvement per tube and assuming these tubes would leak during a postulated main steam line break, the total resulting leakage from these tubes would be:

$$149 \text{ tubes} \times 0.05 \frac{\text{GPM}}{\text{tube}} = 7.45 \text{ GPM}$$

This added to the 0.3 GPM leakage assumed to be present at the start of a postulated main steam line break (which would increase to approximately 0.7 GPM due to MSLB differential pressures) yield a total leakage less than 10 GPM, which has been determined in previous submittals to be an acceptable level of leakage during a postulated MSLB.

B. Regulatory Guide 1.83

The criteria for plugging tubes in this area are established in the regulatory guide.

C. Preventive Plugging Accomplished

The preventive plugging programs that were implemented are indicated in Figures 14, 15, and 16. Both gauging and Regulatory Guide 1.83 program plugging are indicated. Table 3 summarizes this plugging.

Table 3: Summary of Tubes Plugged

	Gauging	R.G. 1.83
SG A	72	6
SG B	48	0
SG C	53	0
	173	6

NOTE: The above figures do not include 6 tubes which were erroneously plugged (1 tube in S/G A, 4 tubes in S/G B, and 1 tube in S/G C)

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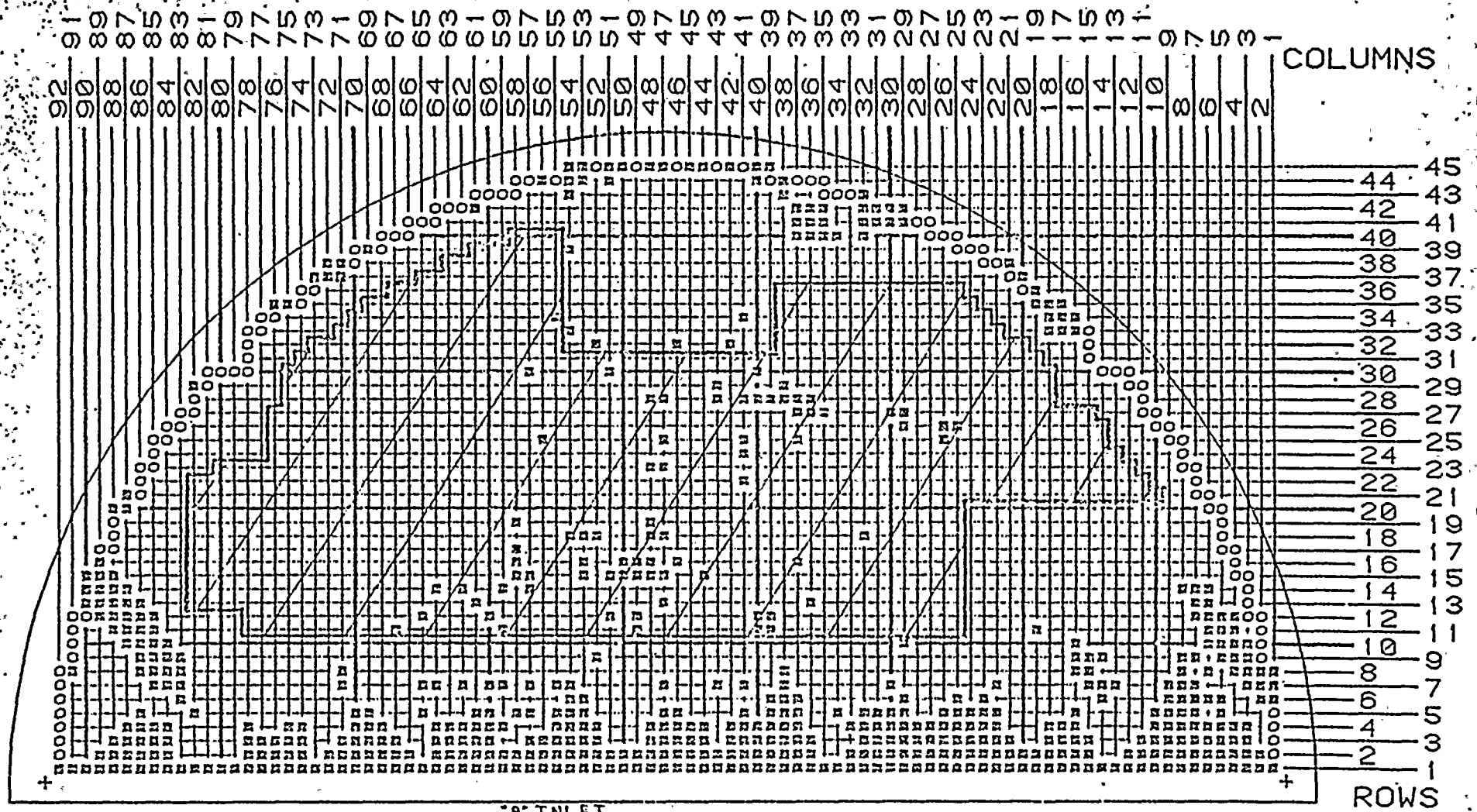

AREA NOT SHADED INDICATES EXTENT OF GAUGING AT 400 KHz
USING .650, .610 AND .540 PROBES THROUGH TOP SUPPORT
TECH. SUPPLEMENT 2; 1,293 TUBES

FIGURE 1

Prepared on Whelan

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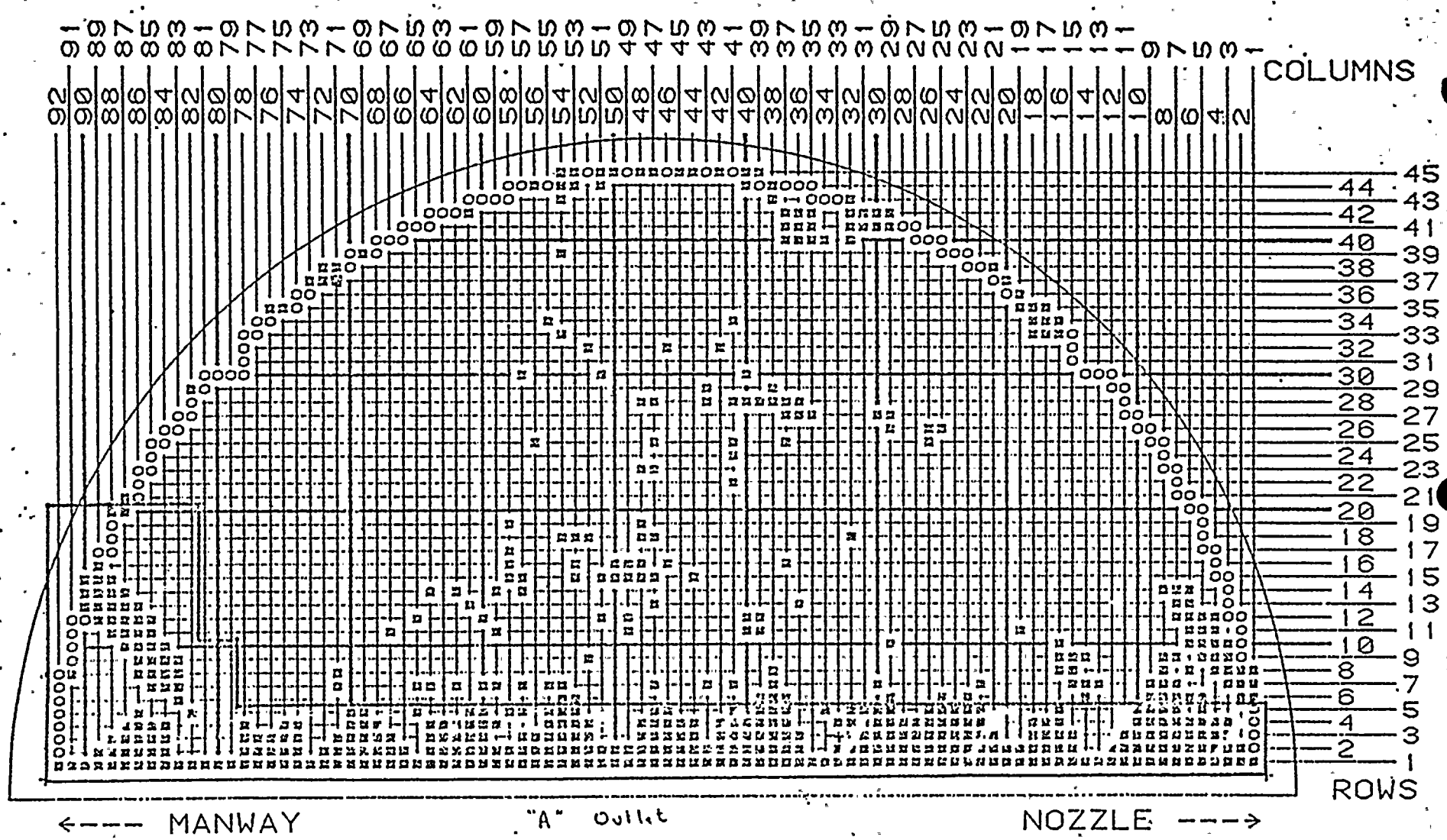

BLOCKED AREA INDICATES AREA OF TUBES TO BE GAUGED AT 400 KHZ USING .610 and .540 PROBES THROUGH TOP SUPPORT - TECH. SUPPLEMENT 2 ; 250 TUBES

Proposed 11/10/78

FIGURE 2

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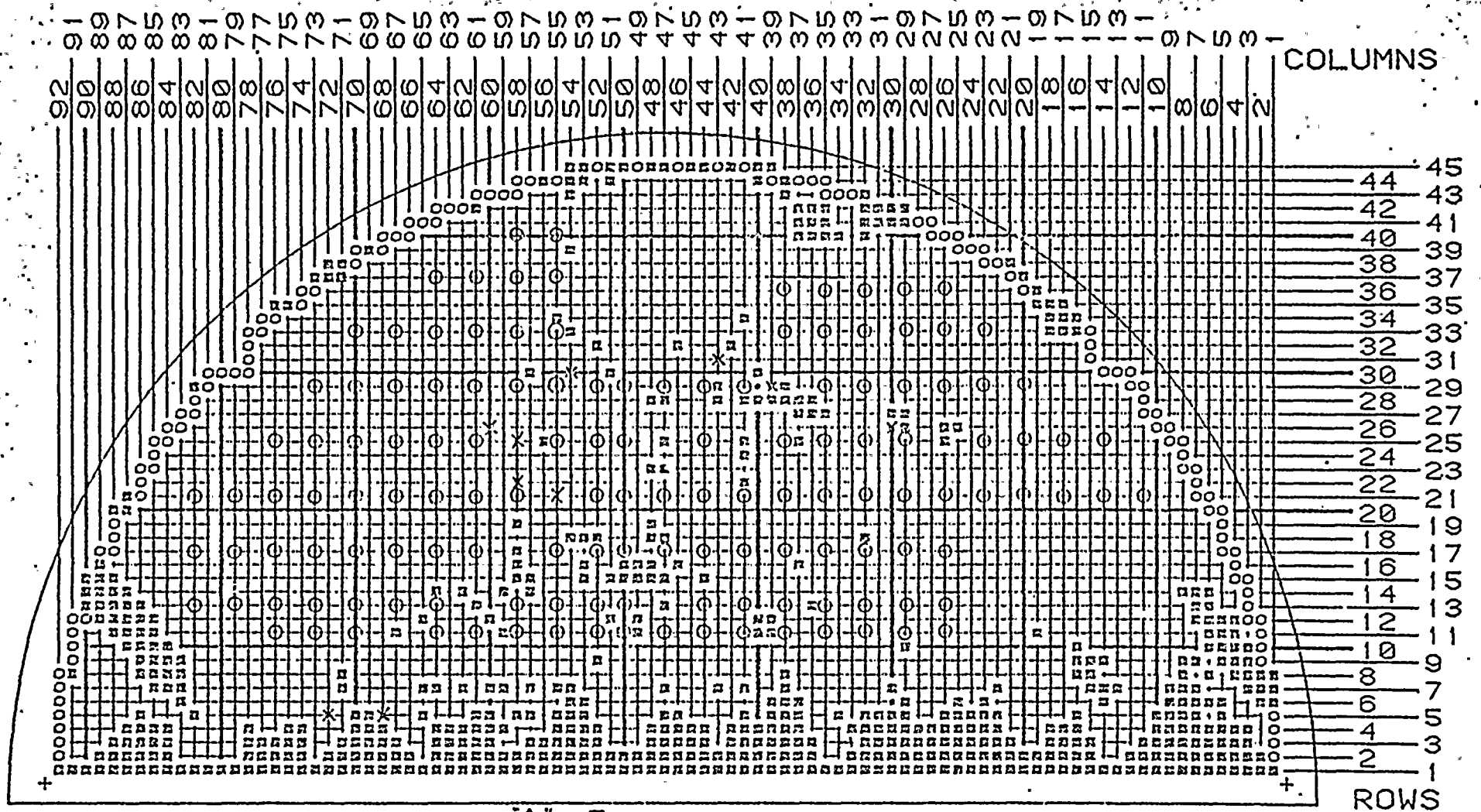

"A" Inlet

←--- MANWAY NOZZLE --->

O - Indicates Tubes To Be Inspected At 400 KHz With .700 Probe Through The U-Bends - Tech. Supplement I ; 137 Tubes

X - Indicates Previous >20% Indications To Be Inspected At 400 KHz With .720 Probe Through 1st Support - Tech. Supplement I ; 10 Tubes

Prepared on 11/15/78

FIGURE 3

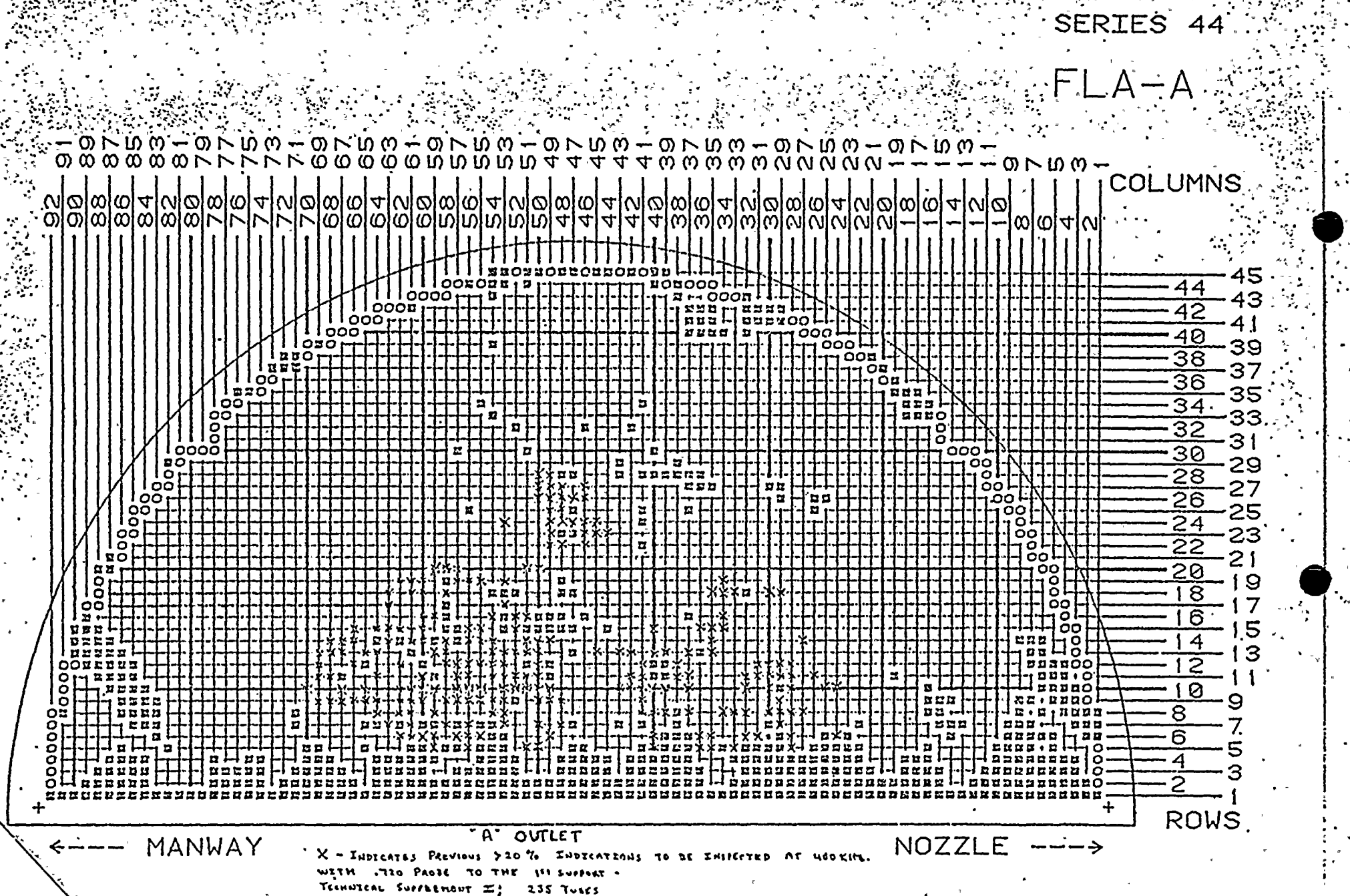
SERIES 44
FLA-A
COLUMNS
ROWS
"A" OUTLET
MANWAY
NOZZLE
X - INDICATES PREVIOUS >20% INDICATIONS TO BE INSPECTED AT 400 KHz.
WITH .720 PROBE TO THE 1ST SUPPORT -
TECHNICAL SUPPLEMENT #; 235 TUBES

FIGURE 4

3	9/74; TUBES PLUGGED	H	1	7/77; WELD REPAIR HL, E/P CL	SERIES 44
3	6/75; TUBES PLUGGED	I	169	2/78; TUBES PLUGGED	
1	DATE NOT KNOWN; TUBES PLUGGED	J	86	8/78; TUBES PLUGGED	
2	SHOP WELD	K	2	SHOP WELD,	
2	5/76; TUBES PLUGGED				FLA-A
1	11/76; TUBES PLUGGED				
2	7/77; TUBES PLUGGED				

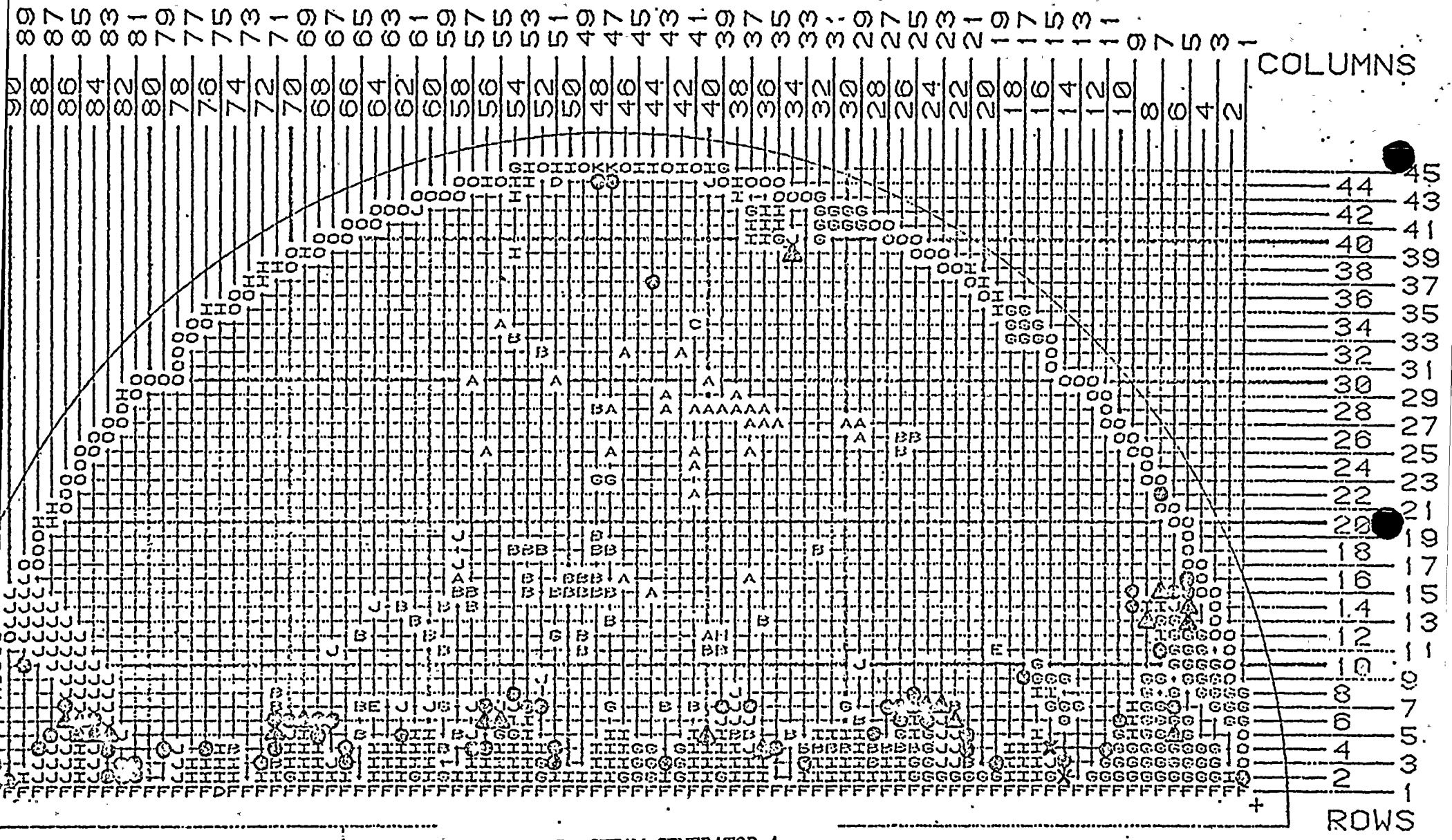

FIGURE 5 STEAM GENERATOR A
GAUGING RESULTS HOT LEG

● = .650" Probe

33	9/74; TUBES PLUGGED	H	1	7/77; WELD REPAIR HL, E/P CL
63	6/75; TUBES PLUGGED	I	169	2/78; TUBES PLUGGED
1	DATE NOT KNOWN; TUBES PLUGGED	J	86	8/78; TUBES PLUGGED
2	SHOP WELD	K	2	SHOP WELD,
2	5/76; TUBES PLUGGED			
91	11/76; TUBES PLUGGED			
32	7/77; TUBES PLUGGED			

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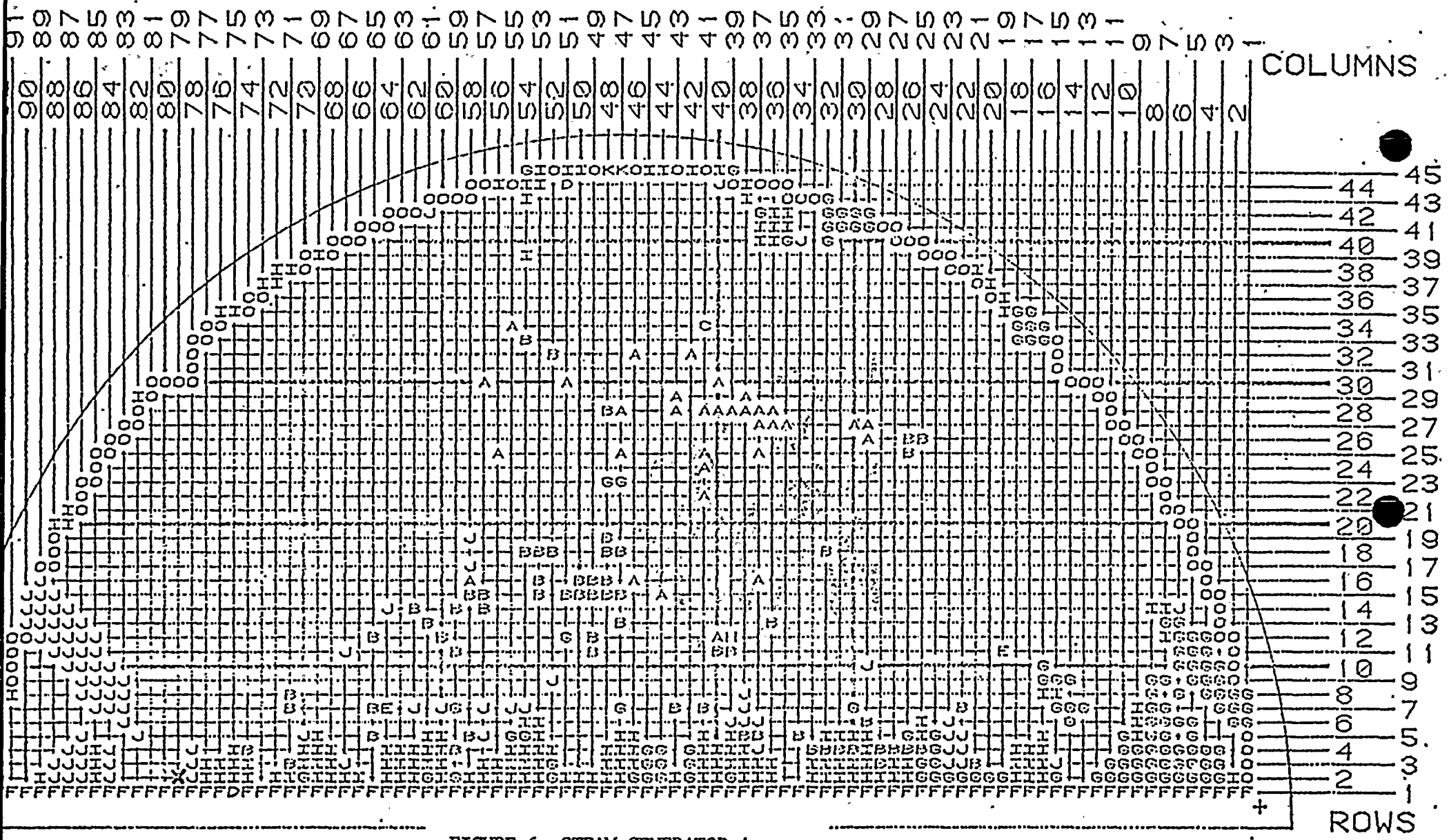

FIGURE 6 STEAM GENERATOR A
GAUGING RESULTS COLD LEG

x = .540" Probe

42	9/74; TUBES PLUGGED	I	48	9/76; TUBES PLUGGED
1	8/75; TUBE PLUGGED	J	100	11/76; TUBES PLUGGED
1	8/75; BARE HOLE PLUG HL-E/P CL	K	1	7/77; WELD REPAIR
66	6/75; TUBES PLUGGED	L	304	7/77; TUBES PLUGGED
1	SHOP WELD	M	9	10/77; TUBES PLUGGED
1	9/75; BARE HOLE PLUGS--HL,CL.	N	75	2/78; TUBES PLUGGED
11	9/75; TUBES PLUGGED	P	28	8/78; TUBES PLUGGED
3	5/76; TUBES PLUGGED			

SERIES 44

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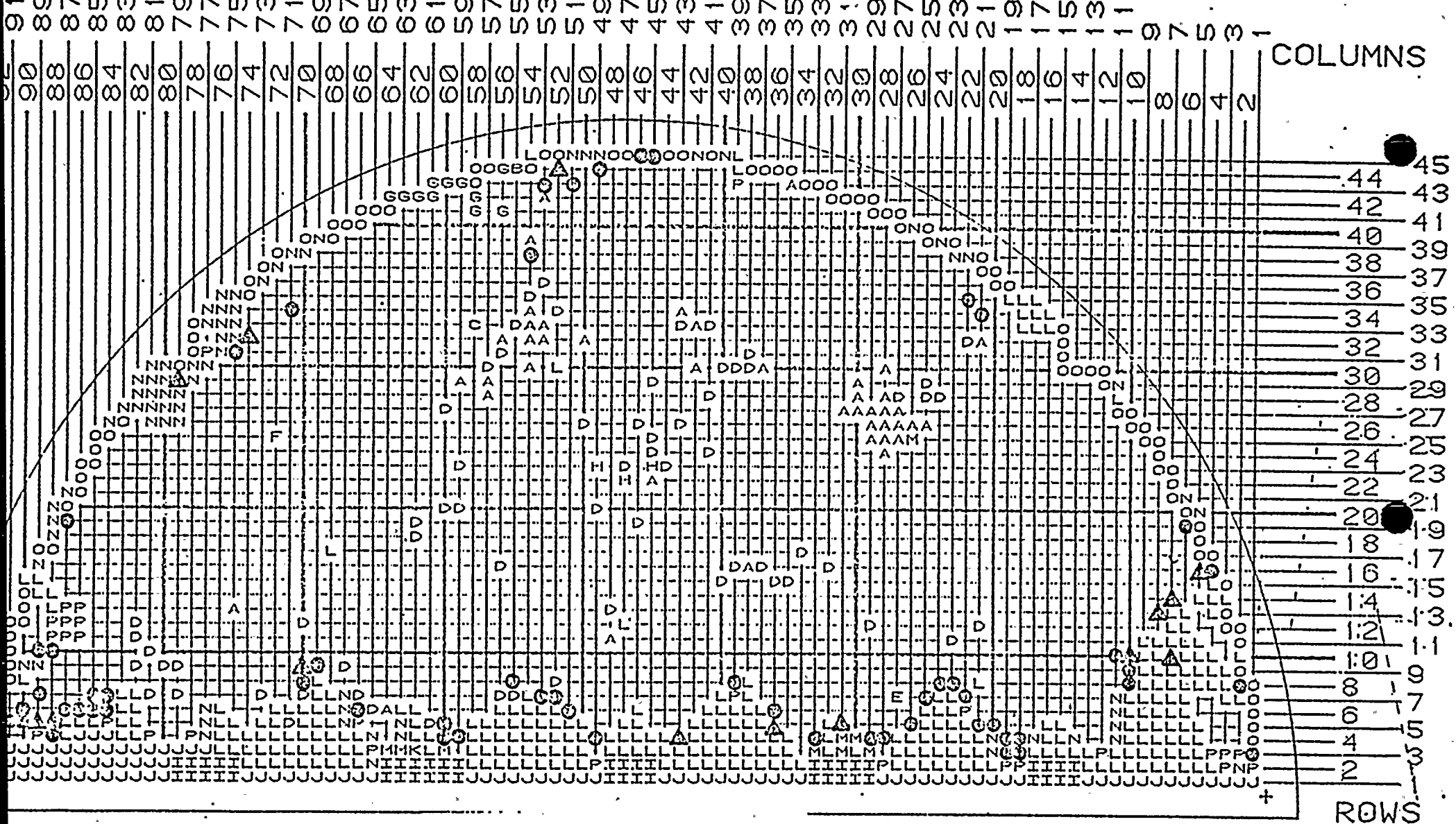


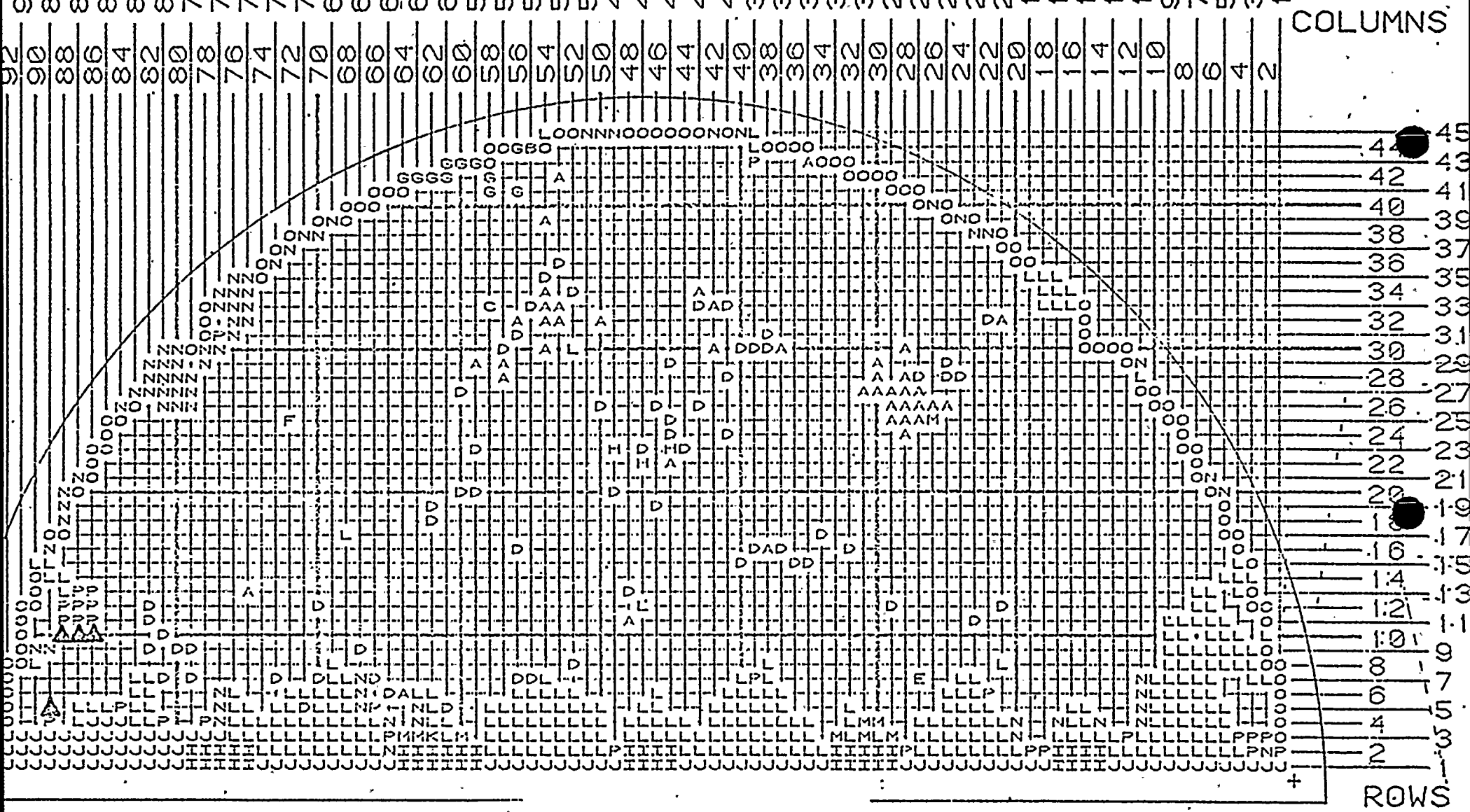
FIGURE 7 STEAM GENERATOR B
GAUGING RESULTS HOT LEG

0 = .650" Probe
Δ = .610" Probe

42	9/74; TUBES PLUGGED	I	48	9/76; TUBES PLUGGED
1	8/75; TUBE PLUGGED	J	100	11/76; TUBES PLUGGED
1	8/75; BARE HOLE PLUG HL-E/P CL	K	1	7/77; WELD REPAIR
66	6/75; TUBES PLUGGED	L	304	7/77; TUBES PLUGGED
1	SHOP WELD	M	9	10/77; TUBES PLUGGED
1	9/75; BARE HOLE PLUGS--HL,CL	N	75	2/78; TUBES PLUGGED
11	9/75; TUBES PLUGGED	P	28	8/78; TUBES PLUGGED
3	5/76; TUBES PLUGGED			

SERIES 44

FLA-B



← MANWAY

NOZZLE →

FIGURE 8 STEAM GENERATOR B
GAUGING RESULTS COLD LEG

Δ = .610" Probe

8	9/74;	TUBES PLUGGED
96	6/75;	TUBES PLUGGED
2	1/76;	TUBES PLUGGED
6	5/76;	TUBES PLUGGED
2	9/76;	TUBES PLUGGED
93	11/76;	TUBES PLUGGED
.5	1/77;	TUBES PLUGGED

H	2	3/77; TUBES PLUGGED
I	9	4/77; TUBES PLUGGED
J	2	7/77; BARE HOLE HL, E/P OUTLET
K	157	7/77; TUBES PLUGGED
L	110	2/78; TUBES PLUGGED
M	62	8/78; TUBES PLUGGED

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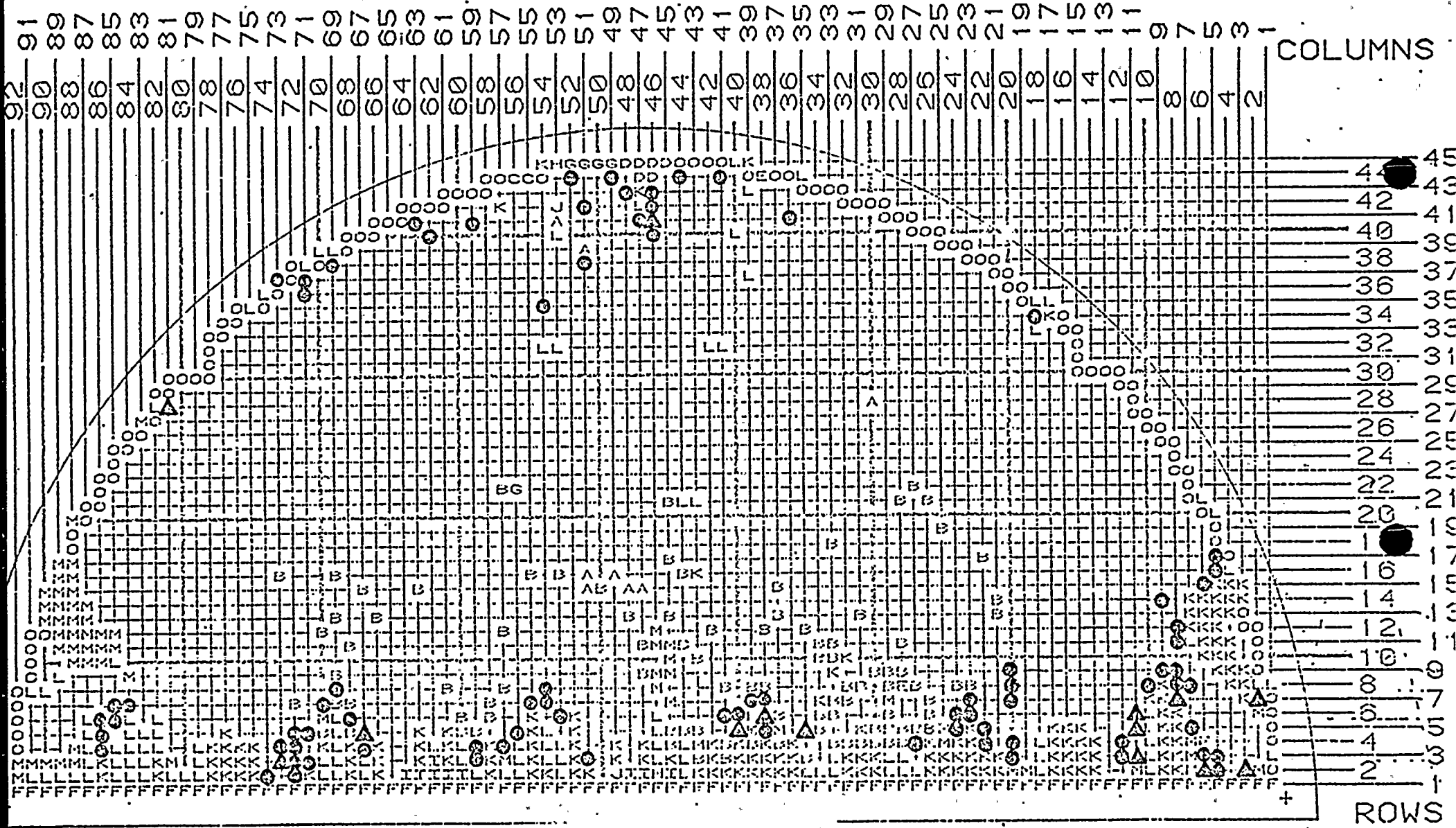

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FIGURE 9 STEAM GENERATOR C
GAUGING RESULTS HOT LEG

0 = .650" Probe
Δ = .610" Probe

8	9/74;	TUBES PLUGGED
96	6/75;	TUBES PLUGGED
2	1/76;	TUBES PLUGGED
6	5/76;	TUBES PLUGGED
2	9/76;	TUBES PLUGGED
.93	11/76;	TUBES PLUGGED
.5	1/77;	TUBES PLUGGED

H	2	3/77; TUBES PLUGGED
I	9	4/77; TUBES PLUGGED
J	2	7/77; BARE HOLE HL, E/P OUTLET
K	157	7/77; TUBES PLUGGED
L	110	2/78; TUBES PLUGGED
M	62	8/78; TUBES PLUGGED

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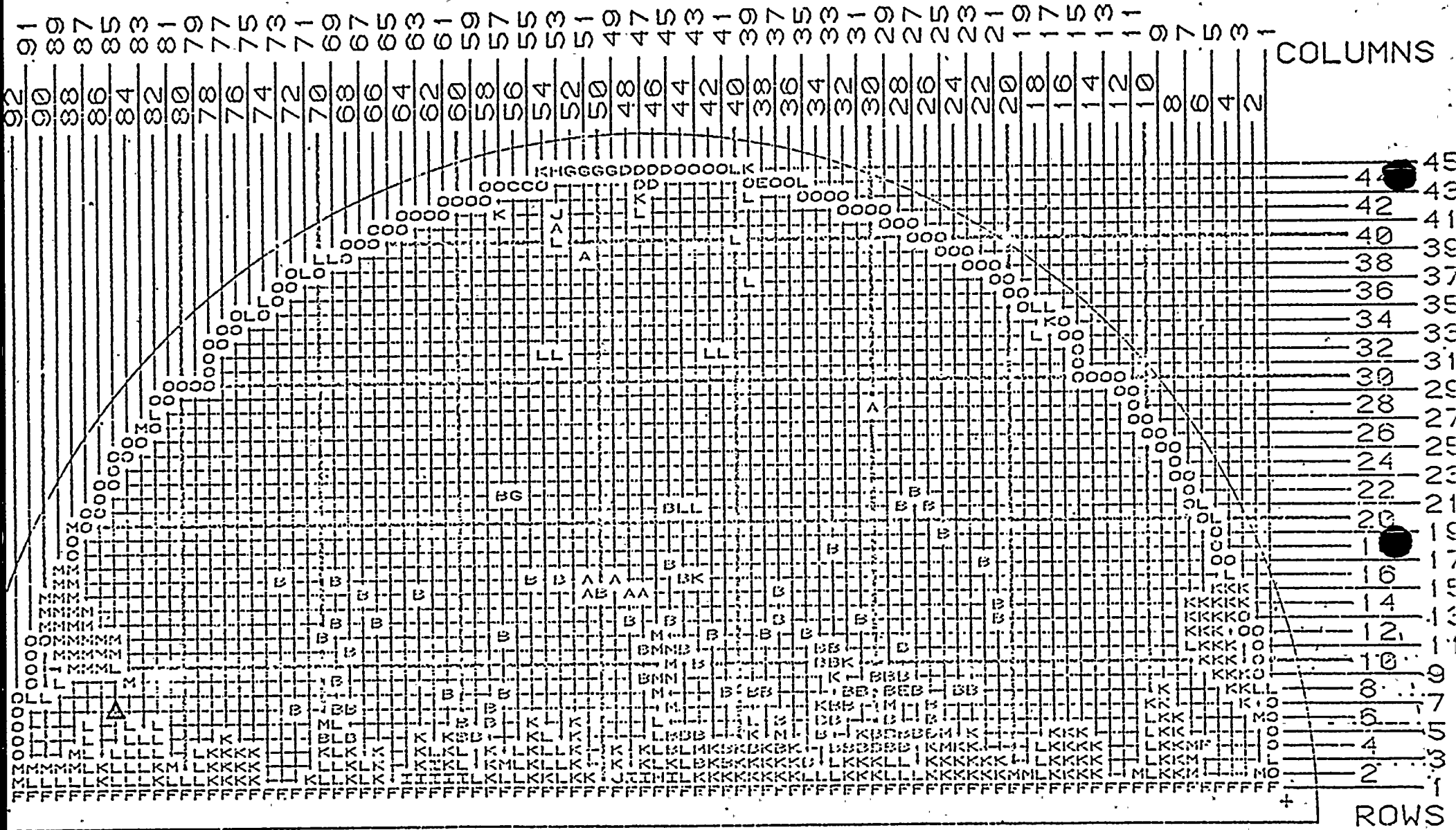

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FIGURE 10 STEAM GENERATOR C
GAUGING RESULTS COLD LEG

△ = .610" Probe

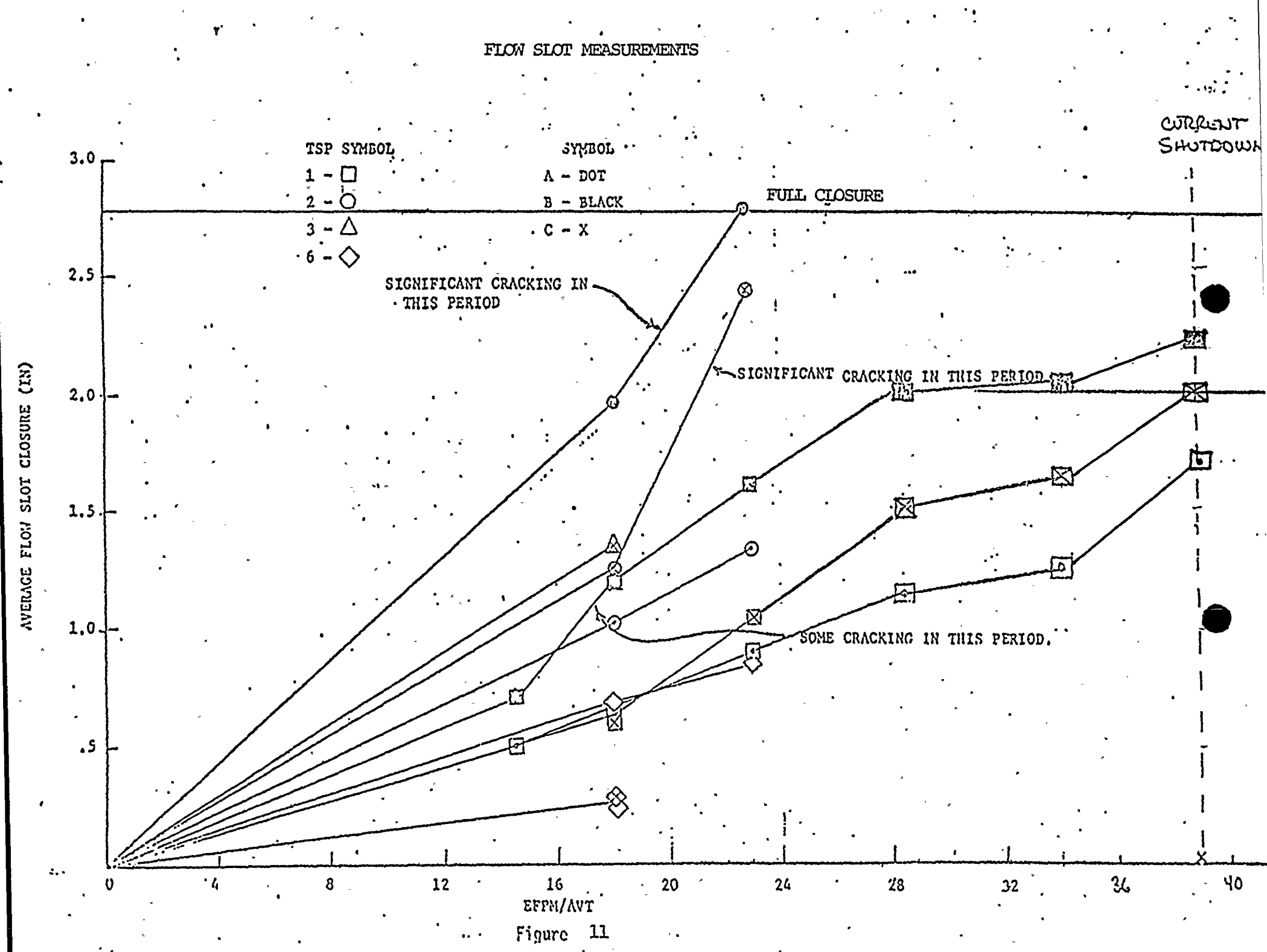
FLOW SLOT MEASUREMENTS
TSP SYMBOL
1 - □
2 - ○
3 - △
6 - ◇
SYMBOL
A - DOT
B - BLACK
C - X
FULL CLOSURE
CURRENT SHUTDOWN
SIGNIFICANT CRACKING IN THIS PERIOD
SIGNIFICANT CRACKING IN THIS PERIOD
SOME CRACKING IN THIS PERIOD.
AVERAGE FLOW SLOT CLOSURE (IN)
3.0
2.5
2.0
1.5
1.0
.5
0
4
8
12
16
20
24
28
32
36
40
EFPM/AVT

Figure 11

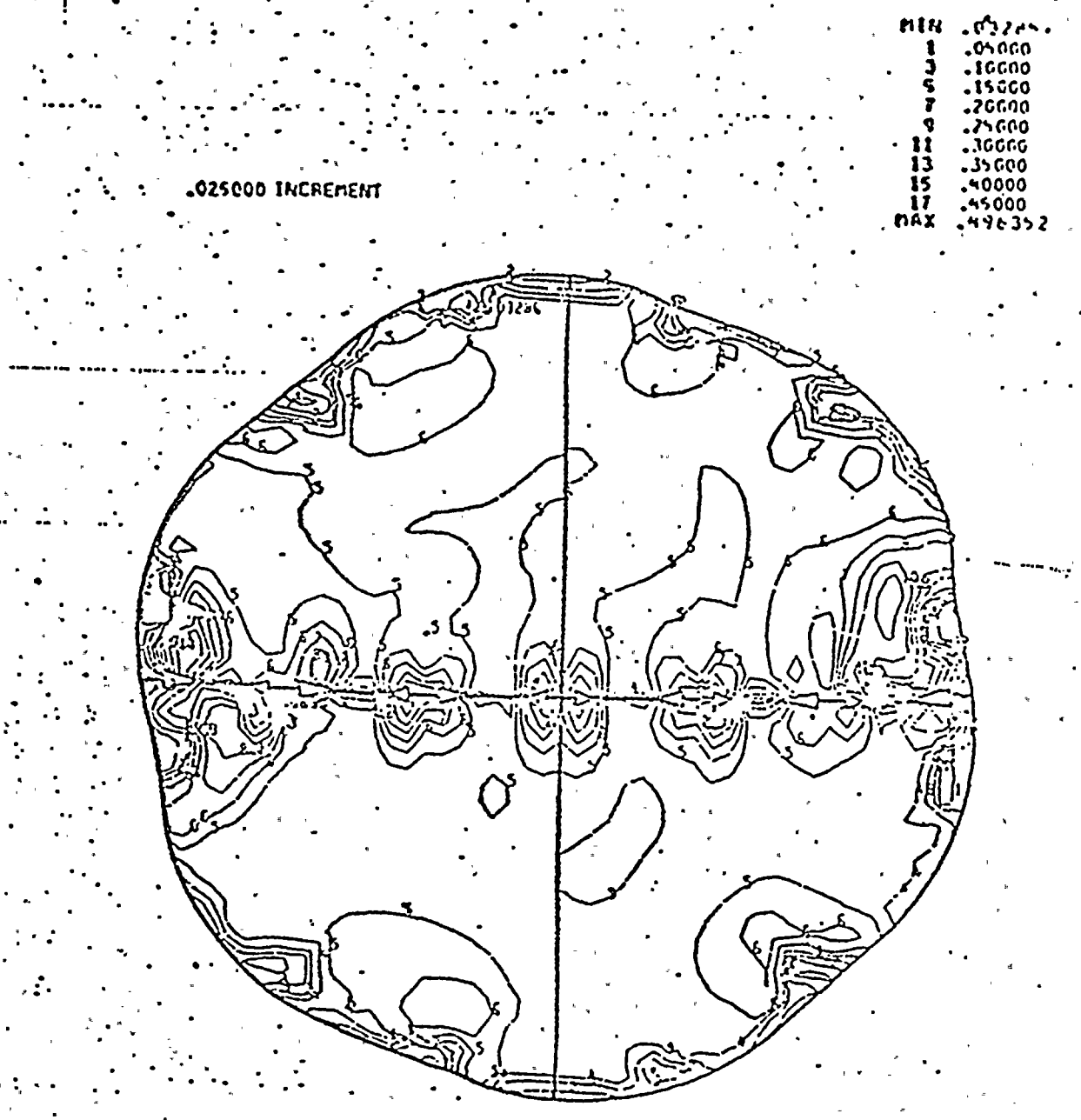

FIGURE 12 TUBE HOOP STRAIN AT 18 EFPM's BEYOND FULL CLOSURE

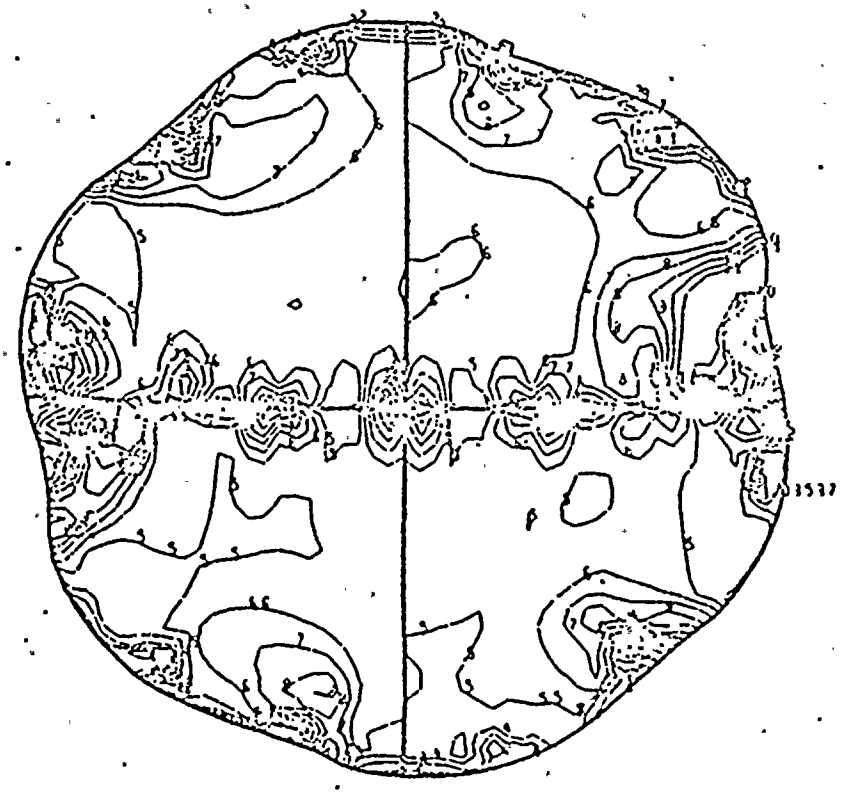

FIGURE 13 TUBE HOOP STRAIN
AT 24 EFPM'S BEYOND FULL CLOSURE

33	9/74; TUBES PLUGGED	H	1	7/77; WELD REPAIR HL, E/P CL
63	6/75; TUBES PLUGGED	I	169	2/78; TUBES PLUGGED
1	DATE NOT KNOWN; TUBES PLUGGED	J	86	8/78; TUBES PLUGGED
2	SHOP WELD	K	2	SHOP WELD,
2	5/76; TUBES PLUGGED			
91	11/76; TUBES PLUGGED			
32	7/77; TUBES PLUGGED			

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FLA-A

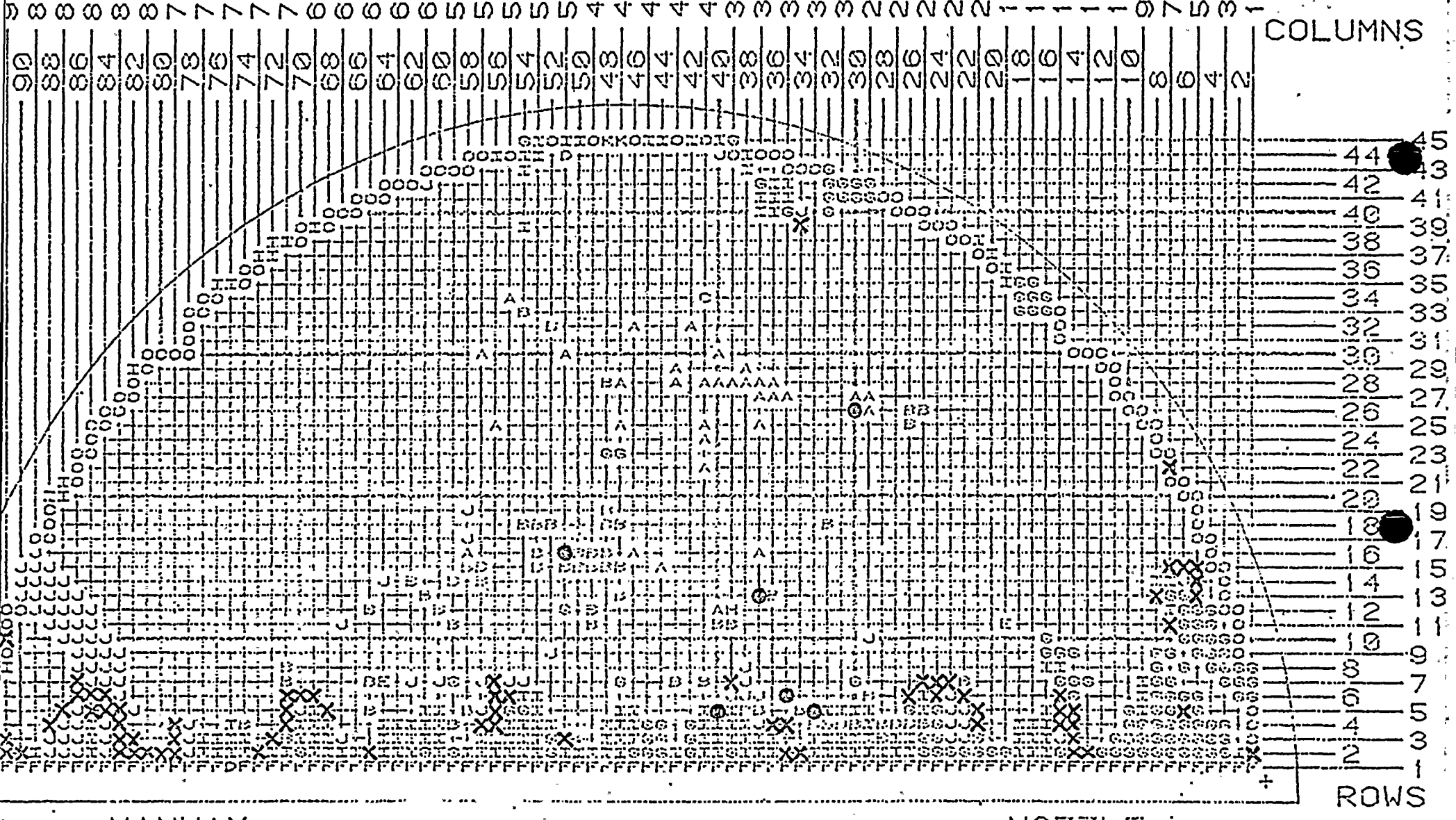


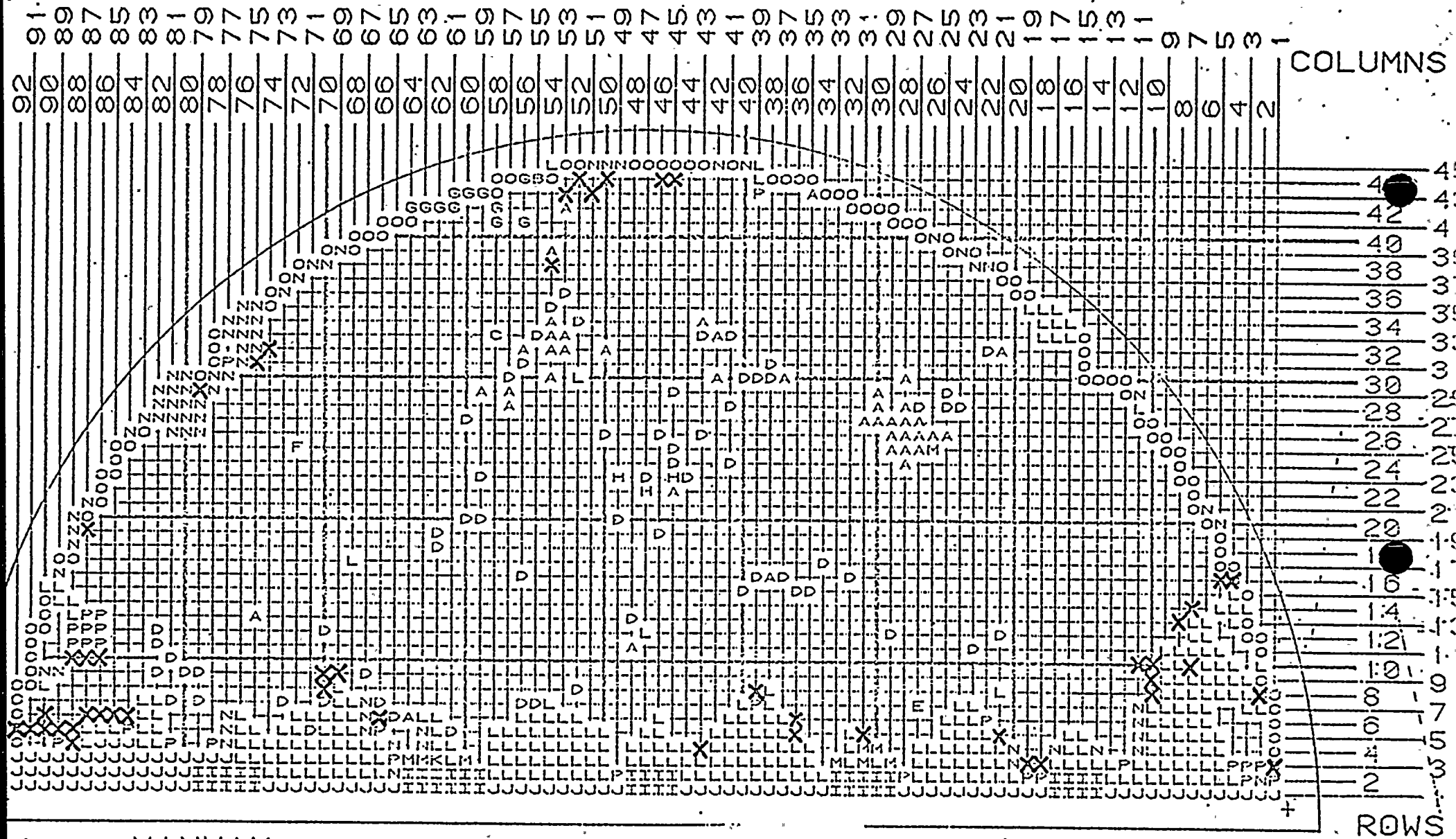
FIGURE 14 STEAM GENERATOR A
PREVENTIVE PLUGGING PATTERN

X = Gauging Plugging
● = R.G. 1.83 Plugging

42	9/74; TUBES PLUGGED	I	48	9/76; TUBES PLUGGED
1	8/75; TUBE PLUGGED	J	100	11/76; TUBES PLUGGED
1	8/75; BARE HOLE PLUG HL-E/P CL	K	1	7/77; WELD REPAIR
66	6/75; TUBES PLUGGED	L	304	7/77; TUBES PLUGGED
1	SHOP WELD	M	9	10/77; TUBES PLUGGED
1	9/75; BARE HOLE PLUGS--HL,CL	N	75	2/78; TUBES PLUGGED
11	9/75; TUBES PLUGGED	P	28	8/78; TUBES PLUGGED
3	5/76; TUBES PLUGGED			

SERIES 44

FLA-B



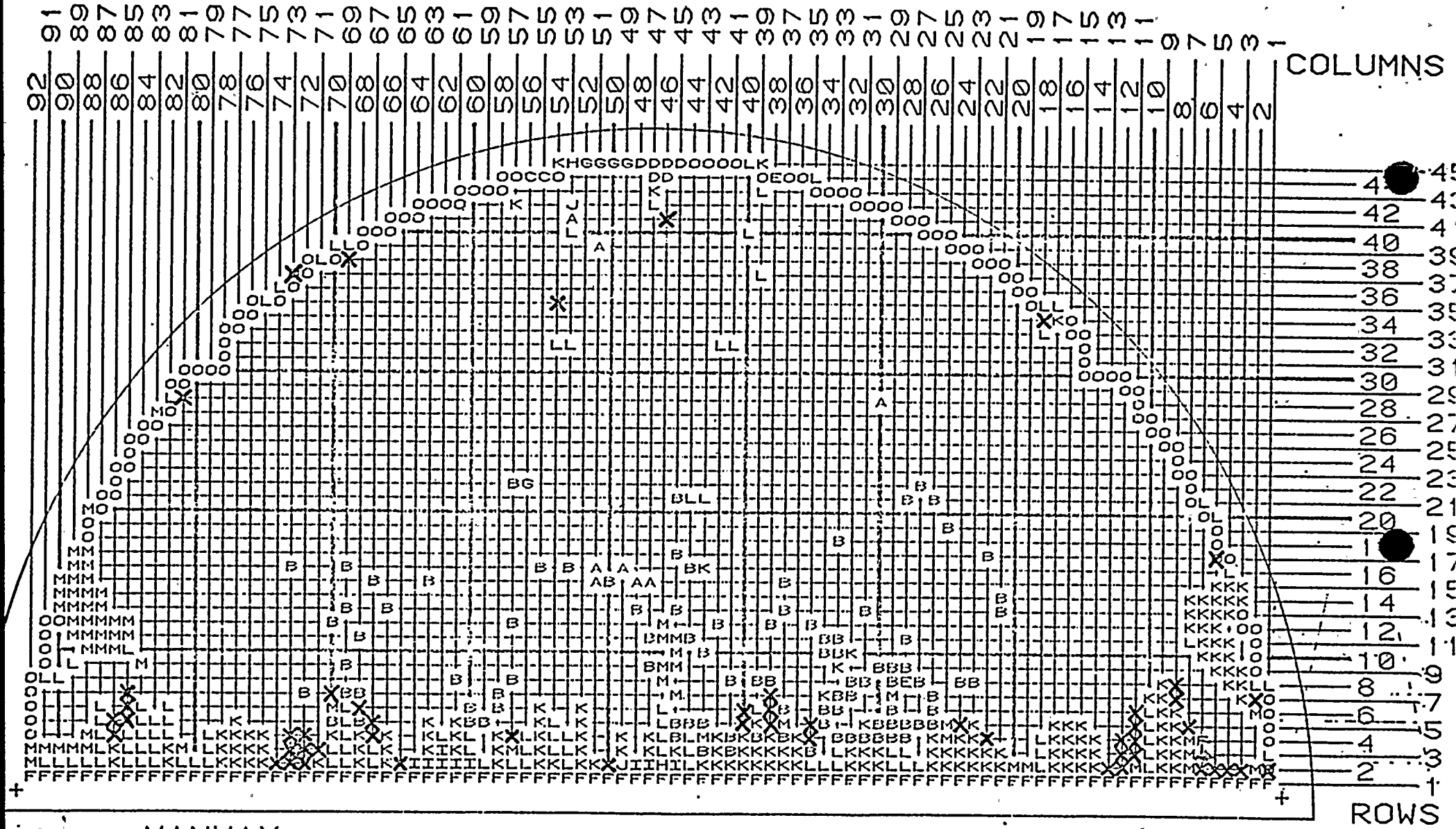
← MANWAY

NOZZLE →

FIGURE 15 STEAM GENERATOR B
PREVENTIVE PLUGGING PATTERN

X = Gauging Plugging

8	9/74; TUBES PLUGGED	H	2	3/77; TUBES PLUGGED	SERIES 44
96	6/75; TUBES PLUGGED	I	9	4/77; TUBES PLUGGED	
2	1/76; TUBES PLUGGED	J	2	7/77; BARE HOLE HL, E/P OUTLET	
6	5/76; TUBES PLUGGED	K	157	7/77; TUBES PLUGGED	FLA-C
2	9/76; TUBES PLUGGED	L	110	2/78; TUBES PLUGGED	
93	11/76; TUBES PLUGGED	M	62	8/78; TUBES PLUGGED	
5	1/77; TUBES PLUGGED				



← MANWAY

NOZZLE →

FIGURE 16 STEAM GENERATOR C
PREVENTIVE PLUGGING PATTERN

X = Gauging Plugging