ATTACHMENT A

Steam Generator Inspection Program and Results

July 1979 Inspection

Consolidated Edison Company of New York, Inc.

Indian Point Unit No. 2
Docket No. 50-247
Facility Operating License No. DPR-26

August, 1979

INSPECTION PROGRAM DESCRIPTION

Following the Indian Point Unit No. 2 steam generator tube inspection in March 1978, the Nuclear Regulatory Commission (NRC) issued Amendment No. 40 to Unit No. 2's Facility Operating License No. DPR-26. The Amendment issued on May 12, 1978, permitted sixteen equivalent months of operation beyond that date. Equivalent operation was defined as operation with a primary coolant temperature greater than 350°F.

By letter from Mr. William J. Cahill, Jr. of Con Edison to Mr. A. Schwencer of the NRC dated April 13, 1979, the details of the steam generator inspection program planned for the Unit's third refueling outage was submitted. By letter dated May 15, 1979, Mr. A. Schwencer of the NRC approved our proposed program with minor changes. The refueling outage was begun on June 16, 1979.

The steam generator inspection program, as conducted during the third refueling outage, included the following:

(1) Steam Generator Eddy Current Examination:

Selected samples of tubes in the hot legs of Steam Generators 21, 22, 23, and 24 were eddy current inspected for both dents and defects. The eddy current inspection for tube defects was performed nominally at 400 KHz at standard gain. The inspection to identify tube dents was performed nominally at 400 KHz at a reduced gain.

(1) Cont'd:

A standard 700 mil eddy current probe was used to perform the eddy current testing. If any tube did not permit passage of this standard 700 mil probe, successively smaller probes were used until the size of the restriction was quantified. In all, five different size probes (700 mil, 675 mil, 640 mil, 610 mil, and 540 mil) were available to quantify the size of a restriction.

In addition, the tubes immediately adjacent to any tube that did not pass the 610 mil probe were also subjected to an eddy current inspection.

Locations of the hot leg tubes in Steam Generators 21, 22, 23 and 24, which were eddy current inspected, are given in Tables 1, 2, 3, and 4 and Figures 1, 2, 3, and 4. In Steam Generator 21, 429 tubes, or about 13.5 percent of all the active tubes in that steam generator, were inspected. In Steam Generator 22, 373 tubes, or about 11.8 percent of all the active tubes, were examined. In Steam Generator 23, 272 tubes, or about 8.6 percent of all the active tubes, were examined. In Steam Generator 24, 396 tubes, or about 12.6 percent of all the active tubes, were examined.

In each steam generator, the eddy current inspection included tubes in the patch plate and peripheral "hard-spot" areas, tubes in rows two and three, and a

(1) Cont'd:

sample of tubes in the interior section of the bundle. The tubes that were inspected in rows two and three were selected from areas of suspected higher stress concentrations near the flow slots. Tubes in row one were not inspected because all the tubes in this row in all four steam generators were plugged during the unit's construction phase when modifications were made to the water box divider plates.

(2) Top Support Plate Inspection of Steam Generators 22 and 23:

The innermost (row number one) steam generator tube U-bends and the flow slots in the top support plates were visually inspected and photographed in Steam Generators 22 and 23. A borescope was utilized to make these observations through the one inch diameter (nominal) "hillside port" provided in the two steam generator shells.

(3) Flow Slot and Lower Support Plate Inspections:

Using the hand holes above the tube sheet for all four steam generators, a visual and photographic examination of the lower tube support plates was made. Where feasible, higher support plates were also photographed through the flow slots in the lower support plates.

(4) Wrapper to Tube Support Plate Annulus Examination:

A photograph was taken using the hand hole above the tube sheet in Steam Generator 24 showing the wrapper to tube support plate contact.

(5) Steam Generator Sludge Analysis:

The sludge that was removed from the steam generator tube sheets during lancing operations was sampled and chemically analyzed.

RESULTS OF THE INSPECTION

(1) Results of Eddy Current Examination:

Average dent size in the tubes of Steam Generators 21, 22, 23 and 24 was not substantially different from that measured during previous steam generator inspections. In Steam Generator 21 the average dent size was 3.1 mils, in Steam Steam Generator 22 the average dent size was 2.4 mils, in Steam Generator 23 the average dent size was 2.7 mils, and in Steam Generator 24 this average was 2.3 mils. The maximum dent indication that was measured with the eddy current probe was 15 mils in Steam Generator 23. Average dent size and maximum dent size in each steam generator are shown in Table 5, with comparison data for the March 1978, April 1977, and June 1976 outages also included. While the dent measurements are in a random pattern, the magnitudes of the measurements are comparable and do not show significant increase or any obvious trend.

Of all the tubes tested, 112 tubes in Steam Generator 21, 76 tubes in Steam Generator 22, 68 tubes in Steam Generator 23, and 107 tubes in Steam Generator 24 did not permit passage of the standard 700 mil eddy current probe. Using successively smaller probes, the size of the restriction in these tubes was quantified and the results are summarized in Table 6. Any tube tested during the inspection that did not permit passage of a 610 mil probe was plugged. In Steam Generator 21, three tubes were plugged; in Steam Generator 22, eleven tubes were plugged (two inadvertently); in Steam

(1) Cont'd:

Generator 23, six tubes were plugged; and in Steam Generator 24, six tubes were plugged (one inadvertently). The tubes that were plugged are identified in Table 7.

(2) Results of Top Support Plate Inspection of Steam Generators 22 and 23:

Flow slots in the top support plate of Steam Generator 22 were measured and photographed during the November 1976, April 1977, and March 1978 steam generator inspection programs. As reported in the Attachments to our November 18, 1976, May 6, 1977, and March 24, 1978 letters, respectively, the results of these inspections indicated no departure from straightness in the flow slots beyond the variations expected in a flame-cut edge.

The inspections of this top support plate performed during this July 1979 inspection indicate that there has been no change in the flow slot width. The flow slots still show no discernible "hour-glassing". The photographs included in Attachment B to this report demonstrate this lack of "hour-glassing" and the similarity in the present condition with that observed during the previous inspections.

In addition, a similar inspection of the top support plate was performed for the first time in Steam Generator 23 during this July 1979 inspection. The results are consistent with those obtained from the Steam Generator 22 inspections.

(2) Cont'd:

Attachment B also includes a photograph of the top support plate in Steam Generator 23, for comparison, demonstrating the lack of discernible "hour-glassing".

(3) Results of Flow Slot and Lower Support Plate Inpsections:

The photographs taken of the lower support plate flow slots during the March 1978 inspection indicated that some "hour-glassing" is apparent in lower flow slots in all four steam generators. For the support plates in Steam Generators 21 and 22 that were examined in April 1977 and again in March 1978, the "hour-glassing" appeared to be essentially unchanged.

During the July 1979 steam generator inspection program, the flow slots in the lower support plates in all four steam generators were again visually examined and photographed using the handholes above the tubesheets. Analysis of the examination results indicates that "hour-glassing" appears to have increased. Average flow slot reduction is less than 10/16 inch for all four steam generators. By comparison, the average flow slot reduction for the March 1978 steam generator inspection program was about 7/16 inch. Average flow slot reduction is tabulated for each steam generator for the July 1979, March 1978 and April 1977 steam generator inspection programs in Table 8. The maximum flow slot reduction observed during the July 1979 inspection was approximately 1-3/8 inch in Steam Generator 22.

(3) Cont'd:

During the March 1978 steam generator inspection program, photographs revealed two cracks in the third flow slot from the manway side in the second tube support plate in Steam Generator 24. The cracks are in the ligaments between the flow slot and first row tube holes near the center of the flow slot. In addition, there was one crack in Steam Generator 23 in the second flow slot from the nozzle side in the third support plate. There is no indication as to when these cracks were formed, as the March 1978 inspection was the first time these areas were examined since the steam generators were fabricated.

Examination of these cracks during the July 1979 steam generator inspection program indicated that the three cracks appear to have opened slightly. In addition, a crack was observed in the third flow slot from the manway side in Steam Generator 22. This slot was not previously examined.

Photographs of the above four cracks observed during the July 1979 steam generator inspection program are presented in Attachment C. Also, included in this Attachment are comparison photographs of the three cracks that were included in the March 1978 photographs.

The integrity of the tubes adjacent to the observed cracks is not compromised because:

(3) Cont'd:

- All row 1 tubes in the four steam generators were plugged during the construction phase when modifications were made to the channel head divider plates. Therefore, all tubes immediately adjacent to the cracks are plugged.

- There is no significant grouping of tubes which did not permit passage of eddy current probes. These "restricted" tubes are distributed in a random manner and only a small number of these tubes are located near the flow lane or near flow slots.

- The eddy current examinations and visual examinations which were just completed indicate that the condition of the Indian Point Unit No. 2 steam generators is better than that observed at other facilities. No tube defects were detected.

- Flow-induced vibration effects in the steam generators are significant where there is cross-flow of the boiler water, as in the region between the tube sheet and the first tube support plate, and in the region above the top tube support plate. In the vicinity of the four support plate cracks that were observed, the boiler water flow is essentially parallel to the tube axis. The vibration effects are, therefore, minimal.

- A conservative Westinghouse analysis, forwarded with a Turkey Point Unit No. 4 (NRC Docket No. 50-251) submittal dated June 9, 1977 and identified as FPL-77-173, Appendix 3C1, indicates that flow induced vibration effects may result in extensive vibration and wear only when three or more tube support plates are missing. This is not the case at Indian Point Unit No. 2.

(4) Results of Wrapper to Tube Support Plate Annulus Examination:

A photograph of the wrapper to tube support plate annulus area was taken in Steam Generator 24 during this July 1979 inspection.

This area appears to be unchanged since the previous examination conducted during the March 1978 inspection. Furthermore, the outer surface of the wrapper was examined, and no evidence of bulging or distortion was found.

(4) Cont'd:

A photograph showing the wrapper and the tube support plate contact is included as Attachment D to this report, together with a comparison photograph from the March 1978 steam generator inspection program.

(5) Steam Generator Sludge Analysis:

Analyses of seven samples of the sludge removed from the steam generators during lancing operations were performed. The results of these analyses are included as Attachment E to this report.

CONCLUSIONS

In conclusion, there is no evidence of severe steam generator degradation as found at other facilities. The July 1979 inspection has demonstrated that the Indian Point Unit No. 2 steam generators are acceptable for continued service.

Based on the results of this inspection program, we are scheduling our next steam generator inspection during the next refueling outage which is planned for the Winter of 1980-1981. In any case, the steam generators will be inspected within sixteen equivalent months of operation following the Unit's return to service after the ongoing refueling outage. For the purpose of this plan, equivalent operation is defined as operation with the primary coolant temperature greater than 350°F.

The proposed schedule for the next inspection is justified for the following reasons:

- Our experience with steam generator tubes has been good. During the operation of Indian Point Unit No. 2 there have been only three instances of primary to secondary leakage which in all cases has been very small. One leak occurred in the first quarter of 1975. The leak was one tube near the tube sheet in Steam Generator 22. The second leak occurred in the fourth quarter of 1976. The leak was in two tubes near the top tube support plate in Steam Generator 24. The third leak occurred in Steam Generator 22 during the second quarter of 1979. Due to its extremely small size (i.e., 0.06 gallons per day), testing has not identified the location of the leak.

- During the steam generator inspection of April 1977, all tubes that did not pass a 700 mil eddy current probe were probed with smaller diameter probes. Eight tubes in Steam Generator 21 and three tubes in Steam Generator 22 were in this category. In five of the eight tubes in Steam Generator 21, a 675 mil probe was passed. In the remaining six, a 610 mil probe was passed. No progressive tube degradation or tube failures were observed during unit operations after this April 1977 inspection.

- Based on the recommendation of the NRC, tubes inspected during the March 1978 inspection which did not pass a 610 mil probe were plugged. No onset of increased tube degradation accompanied by tube leaks occurred after the unit was returned to service following that inspection.

- Tubes inspected during the July 1979 inspection which did not pass a 610 mil probe were plugged. Of all the tubes that were plugged, only one would not pass the 540 mil probe. No onset of increased tube degradation accompanied by tube leaks is expected to occur when the unit is returned to service following the present outage.

- Should any tube leak occur, our present Technical Specifications, section 3.1.F, require a thorough assessment of its significance. The reactor must be brought to a cold shutdown condition within 24 hours if leakage in any steam generator exceeds 0.3 gpm, or if the leakage frequency is two or more tubes within a period of 20 days. Under these circumstances, NRC approval to resume reactor operation must be obtained and Con Edison must inform the NRC before any tube is plugged or repaired.

- The eddy current examinations and visual examinations that were completed in March 1978 and July 1979 indicate that the condition of the Indian Point Unit No. 2 steam generators is much better than was observed at those facilities where preventive plugging is being implemented. There is less "hour-glassing" of flow slots, fewer tubes that are "restricted" and fewer instances of primary to secondary tube leaks at Indian Point Unit No. 2.

- Westinghouse has reviewed the results of our steam generator inspections. Based upon analysis performed for similar steam generators at other facilities, operation of the Indian Point Unit No. 2 steam generators is justified for a period in excess of 16 months.

TABLE 1

Tubes Inspected

Steam Generator No. 21

Row	Col.	No. of Tubes
2	11 to 20 27 to 33 56 to 66 73 to 82	38
3	11 to 20 27 to 29 56 to 66 73 to 82	34
6	51	1
7	1 to 5 88, 90, 91, 92	9
8	1 to 5 88 to 92	10
9	2 to 5, 51 88 to 91	9
10, 11	2 to 5 88 to 91	16
12	2 to 5, 51 88 to 91	9
13, 14	3 to 5 88 to 90	12
15	3 to 5, 51 88 to 90	7
16, 17	4 and 5	4
18	5, 6 and 51	3
19, 20	5 and 6	4
21	6 and 7, 15, 18, 21, 24, 27, 30 33, 36, 39, 42, 45, 48, 51	15
22, 23	7 and 8	4
24	8, 9, 51	3
25	8, 9	2
26	9, 10	2

TABLE 1 (CONT'D)

Steam Generator No. 21

Row	Col.	No. of Tubes
27	10, 11, 51	3
28, 29	11 to 17 76 to 82	28
30	12 to 17, 51 76 to 81	13
31	15 to 17 76 to 78	6
32	15 to 17, 39 to 54 76 to 78	22
33	15 to 17 39 to 54 76, 77	21
34	16, 17, 39, 40 53, 54, 76	7
35	17, 18, 39, 40, 53, 54, 76	7
36	19, 20, 39, 40, 53, 54	6
37	20, 21, 39, 40, 53, 54	6
38	21, 22, 39, 40, 53, 54	6
39	23, 24, 39, 40, 53, 54	6
40	25 to 27, 39, 40, 53	6
41	27 to 40, 53 to 66	28
42	29 to 40, 53 to 64	24
43	32 to 40, 53 to 61	18
44	35 to 58	24
45	39 to 54	16
	Total No. of Tubes	429

TABLE 2

Tubes Inspected

Steam Generator No. 22

Row	Col.	No. of Tubes
2	12 to 21 28 to 41 57 to 67 74, 76 to 83	44
3	12 to 21 28 to 37 57 to 67 74 to 83	41
6	50, 51	2
7	2 to 4	3
8	2 to 5	4
9	3 to 5, 50, 51	5
10, 11	3 to 5	6
12	3 to 5, 50, 51	5
13, 14	4 to 6	6
15	4, 5, 50, 51	4
16, 17	5	2
18	6, 50, 51	3
19, 20	6	2
21	7, 13, 15, 16, 18, 19, 21, 22, 24 25, 27, 28, 30, 31, 33, 34, 36, 37 39, 40, 42, 43, 45, 46, 48 to 51	28
22, 23	8	2
24	9, 51	2

TABLE 2 (CONT'D)

Steam Generator No. 22

Row	Col.	No. of Tubes
25	9	1
26	10	1
27	11, 51	2
28, 29	12 to 17 77 to 82	24
30	13 to 17 50, 51 78 to 81	11
31	16, 17	4
32	16, 17, 39 to 54, 77, 78	20
33	16, 17, 39 to 55, 77, 78	20
34	17, 40, 53, 54, 77	5
35	18, 39, 40, 53, 54	5
36	19, 20, 40, 49, 54	5
37	20, 21, 40, 49, 54	5
38	21, 22, 40, 49, 54	5
39	23, 24, 40, 49, 54	5
40	25, 26, 27, 40, 49, 54	6
41	28 to 40, 54 to 66	26
42	30 to 41, 53 to 64	24
43	33 to 41, 53 to 61	18
44	36 to 53	18
45	40 to 50	11
	Total No. of Tubes	373

TABLE 3

Tubes Inspected

Steam Generator No. 23

Row	Col.	No. of Tubes
2	14 to 16, 18 to 37 49 to 60	35
3	1 to 4, 6 to 27 29 to 37	35
4	1 to 14	14
7	1 to 6	6
8	1 to 4, 6	5
9	2 to 6, 46	6
10, 11	2 to 6	10
12	2 to 6, 46	6
13, 14	3 to 6	8
15	3 to 6, 46	5
18	46	1
21	34, 37, 40, 43, 46	5
24, 27	46	2
28	11 to 16	6
29	11 to 13, 15 to 17	6
30	12 to 17, 46	7
31	15 to 17	3
32	15 to 17, 39 to 44, 46	10
33	15 to 17, 39 to 46	11
34	16, 17, 39, 40	4
35	17, 39, 40	3
36, 37, 38, 39	39, 40	8
40	31 to 33, 40	4
41	27 to 40	14

TABLE 3 (CONT'D)

Steam Generator No. 23

Row	Col.	No. of Tubes
42	29 to 40	12
43	32 to 39	8
44	35 to 51, 53 to 58	23
45	39 to 53	15
	Total No. of Tubes	
		272

TABLE 4

Tubes Inspected

Steam Generator No. 24

Row	Col.	No. of Tubes
2	2 to 20, 26 to 31 53 to 66, 73 to 83	50
3	10 to 20, 26 to 31 56 to 66, 73 to 83	38
7	1 to 5	5
8	1 to 5, 88 to 92	10
9, 10, 11	2 to 5, 88 to 91	24
12	2 to 5, 46, 88 to 91	9
13, 14	3 to 5, 88 to 90	12
15	3 to 5, 46, 88 to 90	7
18	46	1
21	13, 16, 19, 22, 25, 28, 31 34, 37, 40, 43, 46	12
24	46	1
27	10 to 17, 46	9
28	13 to 17, 77 to 82	11
29	11 to 17, 76 to 82	14
30	12, 13, 16, 17, 46 76 to 81	11
31	15 to 17, 76 to 78	6
32	15 to 17, 39 to 54 76 to 78	22
33	15 to 17, 39, 40, 42 to 54, 76 to 78	21
34	16, 39, 40, 53, 54, 76, 77	7
35	18, 39, 40, 53, 54, 75, 76	7
36	39, 40, 54	3
37, 38, 39	39, 40, 53, 54	12

TABLE 4 (CONT'D)

Steam Generator No. 24

Row	Col.	No. of Tubes
40	39, 40	2
41	27 to 40, 53, 54 56 to 66	27
42	29 to 40, 53 to 64	24
43	32 to 40, 53 to 61	18
44	35, 39 to 53, 57, 58	18
45	40 to 54	15
		Total No. of Tubes
		396

TABLE 5

Dent Measurements (mils)

Steam Generator	July 79		April 77		June 76	
	Average	Max	Average	Max	Average	Max
21	3.1	13	3.0	20	4.2	15
22	2.4	9	2.7	10	2.7	9
	July 79		March 78		June 76	
23	2.7	15	2.6	9	4.3	12
24	2.3	9	2.2	9	3.4	10

TABLE 6

Restricted Tubes, July 1979

Steam Generator	<700	<675	<640	<610	<540 mil probe
21	112	39	10	3	0
22	76	26	13	9	0
23	68	31	9	6	0
24	107	53	7	5	1

TABLE 7

Tubes Plugged, July, 1979

Steam Generator	Tube	Support Plate*
21	R15C90	6
	R35C17	2
	R44C41	1
22	R2 C17	4
	R2 C19	***
	R2 C20	1
	R2 C31	***
	R2 C32	1
	R2 C33	1
	R28C82	1
	R33C18	1
	R34C16	**
	R34C17	1
	R44C40	1
23	R39C34	6
	R40C35	6
	R41C32	6
	R41C36	6
	R42C37	6
	R43C38	6
24	R2 C57	1
	R8 C3	1
	R27C10	6
	R27C11	***
	R28C13	6
	R35C18	6

*Support Plate Level at which 610 mil probe was obstructed. All tubes except R2C57 permitted passage of 540 mil probe.

**Tube R34C16 was not examined and was plugged because of the restriction in Tube R34C17.

***Tubes R2C19, R2C31 in SG 22 and R27C11 in SG 24 were plugged inadvertently.

TABLE 8

Average Flow Slot Reduction (inches)

Steam Generator	July 79	March 78	April 77
21	0.65 (18)*	0.29 (15)	0.35 (16)
22	0.57 (14)	0.41 (6)	0.26 (12)
23	0.78 (16)	0.77 (14)	-
24	0.47 (15)	0.38 (15)	-

* (Numbers in parentheses indicates numbers of flow slots measured.)

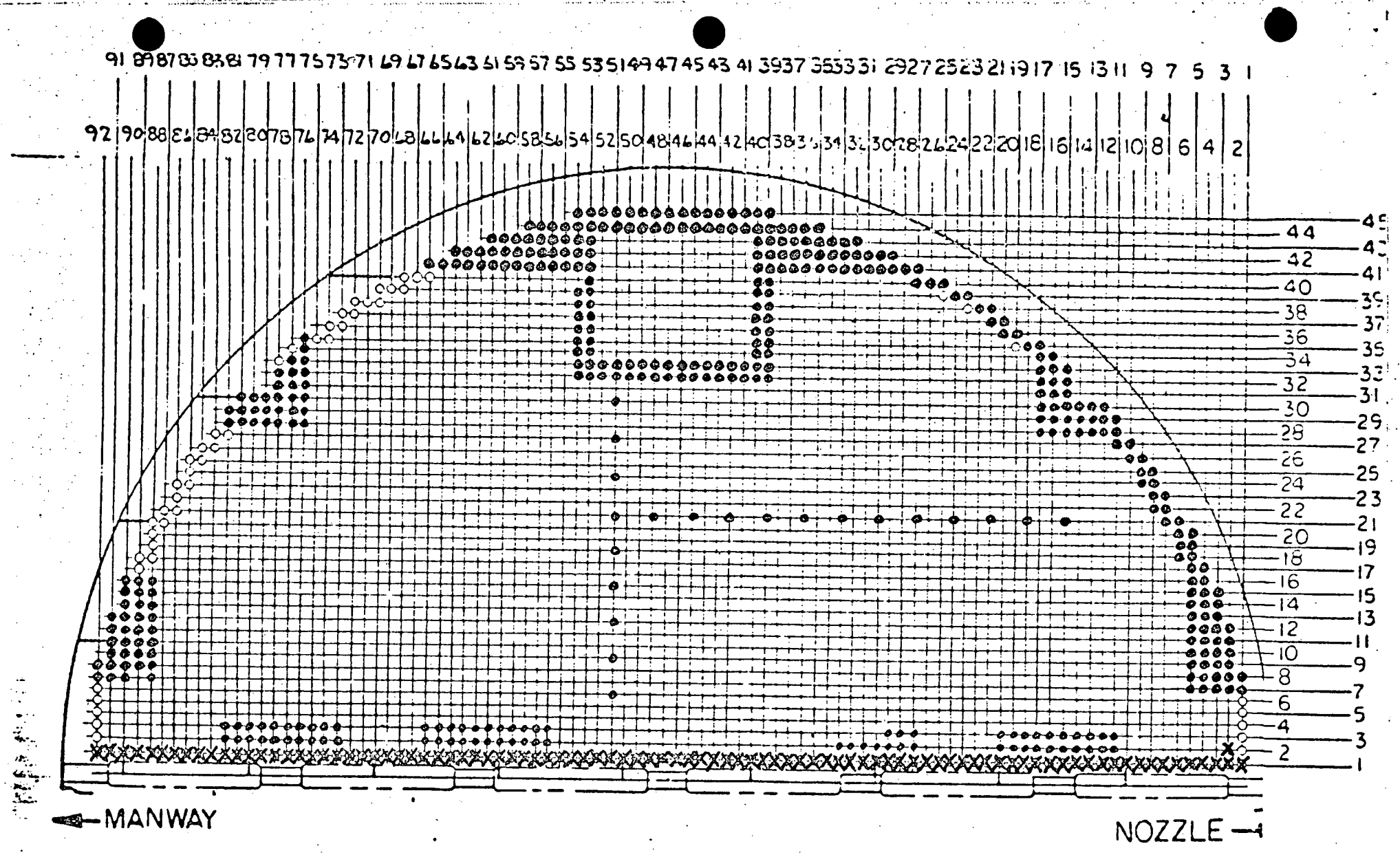

FIGURE 1

Steam Generator 21

July 1979 Inspection

● - Tubes inspected (429).

✕ - Tubes previously plugged.

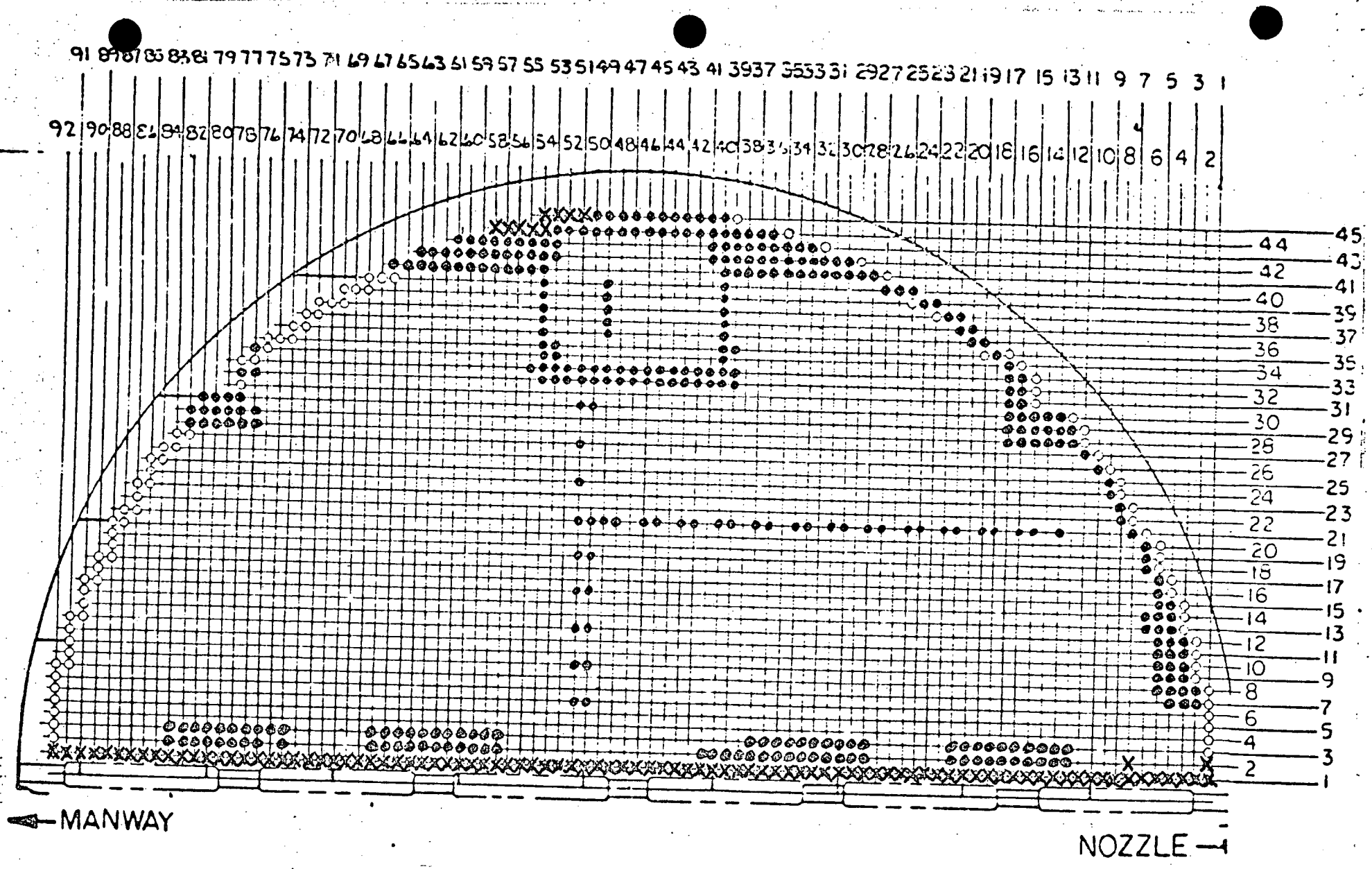

FIGURE 2

Steam Generator 22

July 1979 Inspection

● - Tubes inspected (375).

X - Tubes previously plugged.

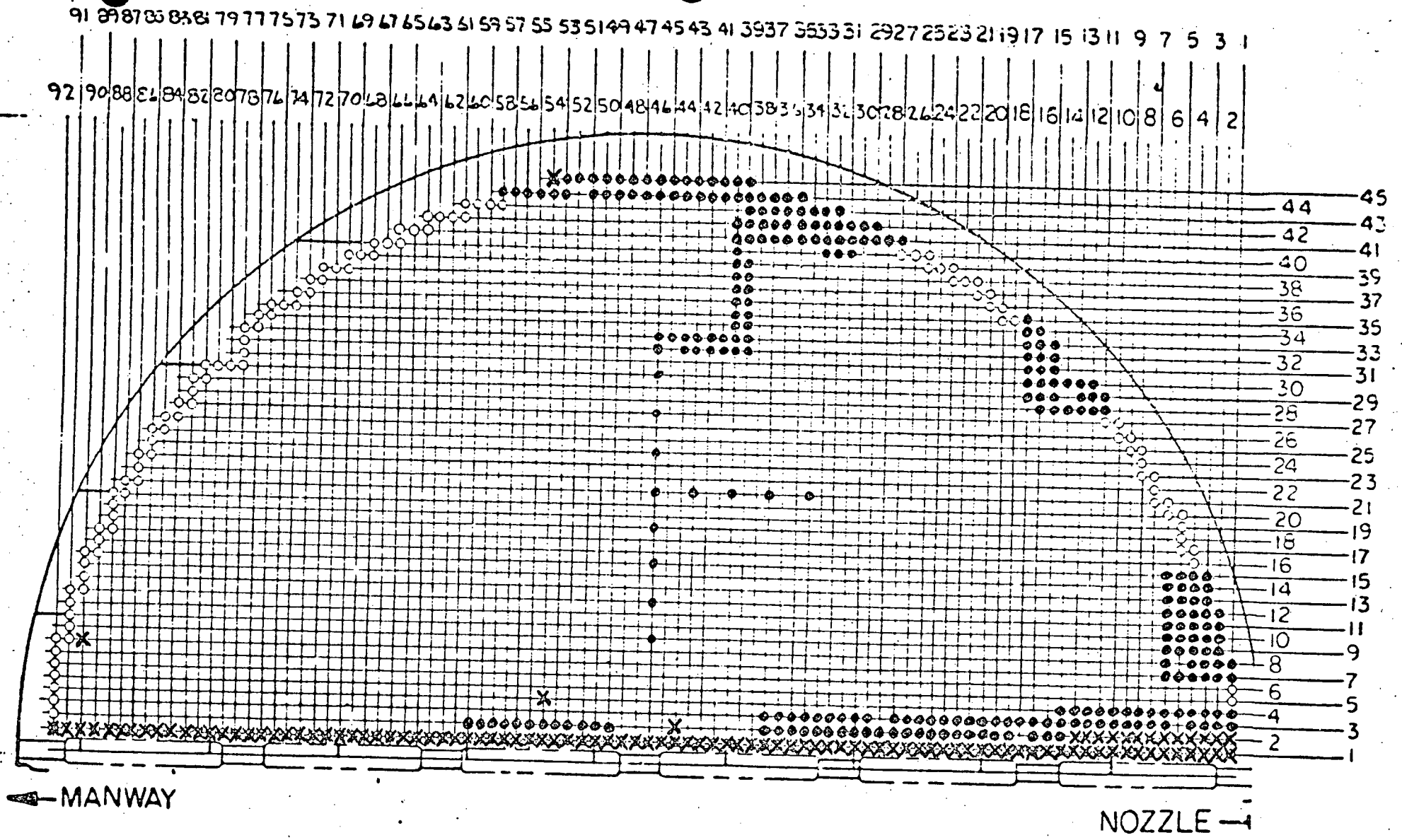

FIGURE 3

Steam Generator 23

July 1979 Inspection

● - Tubes inspected (272).

✕ - Tubes previously plugged.

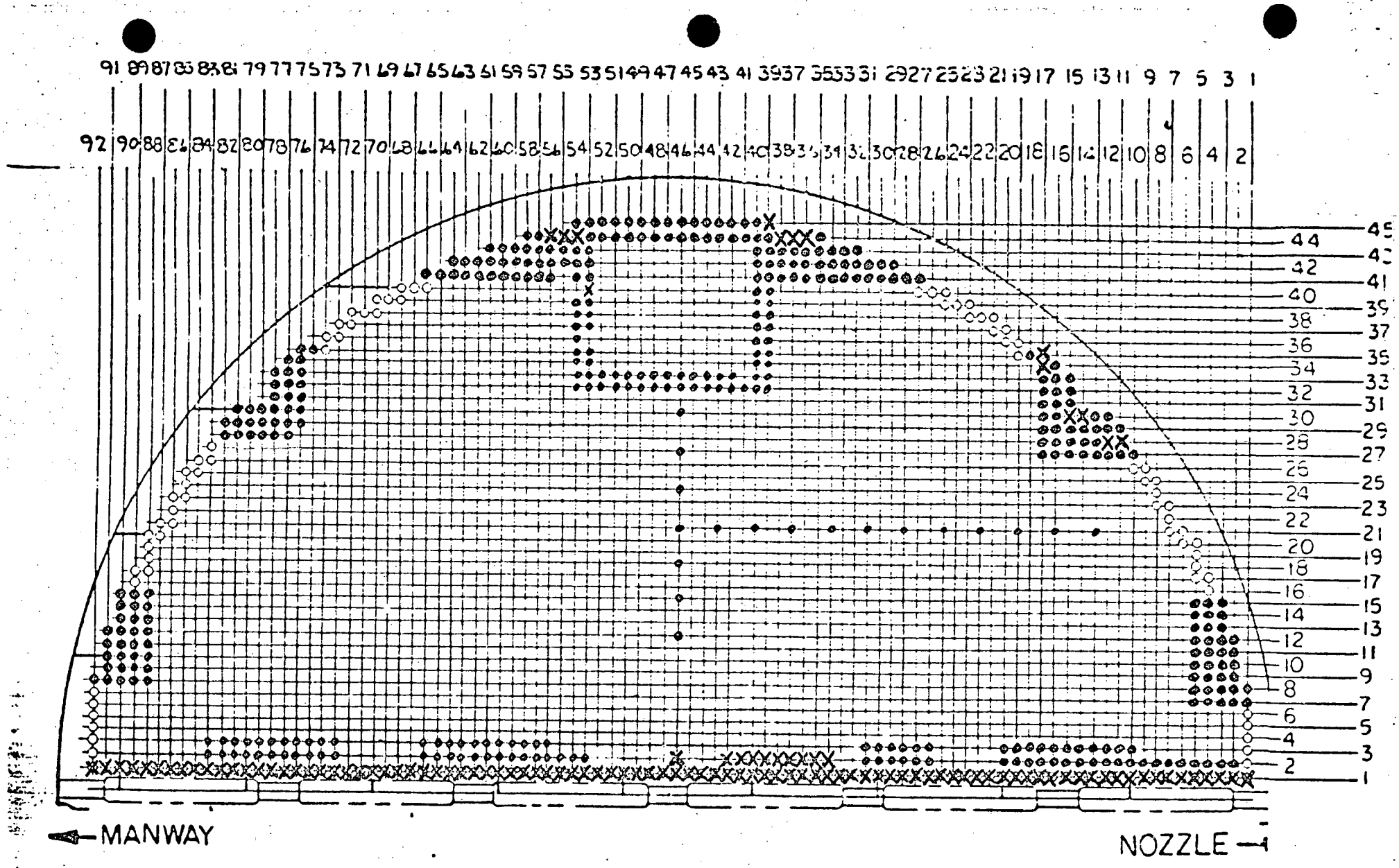

FIGURE 4

Steam Generator 24

July 1979 Inspection

● - Tubes inspected (396).

X - Tubes previously plugged.

ATTACHMENT B

Photographs of Top Tube Support Plate Flow Slots

Steam Generators Nos. 22 and 23

July 1979 Inspection

Consolidated Edison Company of New York, Inc.

Indian Point Unit No. 2
Docket No. 50-247
Facility Operating License No. DPR-26
August, 1979

April, 1977

March, 1978

July, 1979

Top support plate with undeformed flow slots, as seen through a borescope.

Steam Generator 22, Indian Point 2.

July 1979

Top support plate, as seen through a borescope,
Steam Generator 23, Indian Point 2.

ATTACHMENT C

Photographs of Lower Tube Support Plate Flow Slots

July 1979 Inspection

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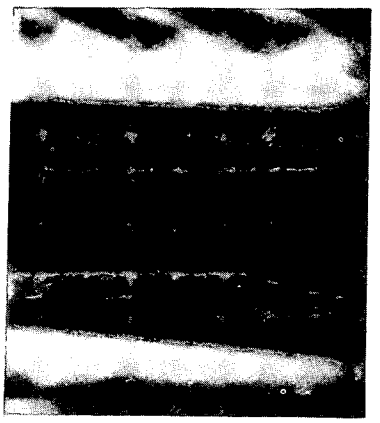
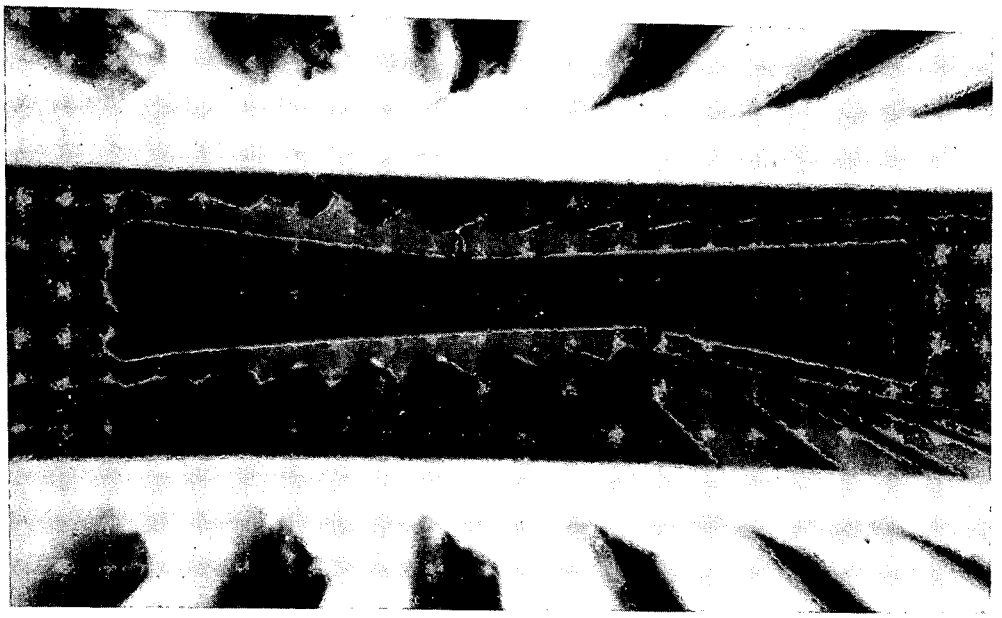


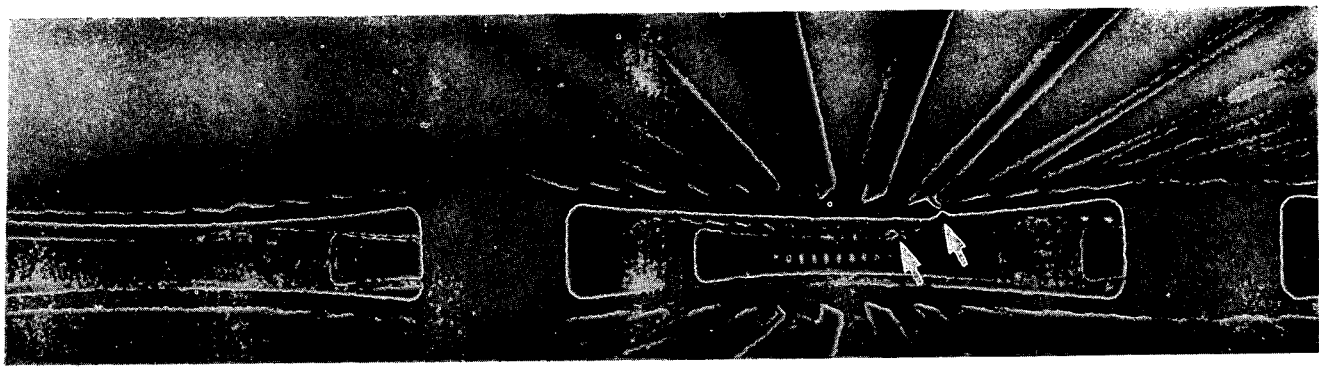
March, 1978



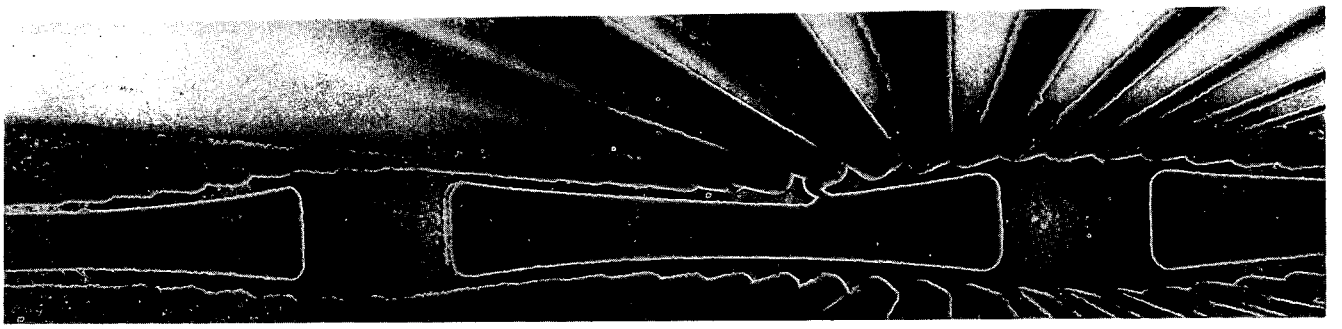
July, 1979

Cracked support plate.

Steam Generator 24, support plate 2
Indian Point 2



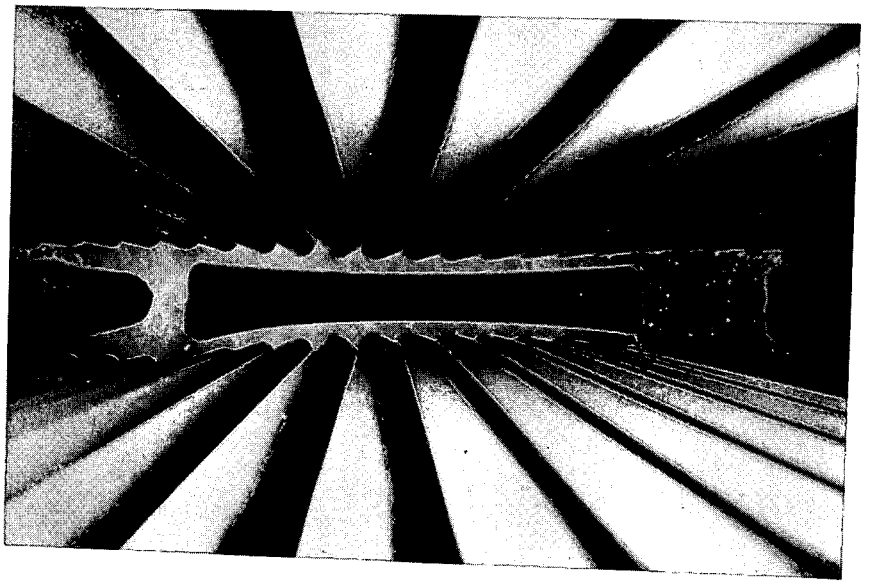
March, 1978



July, 1979

Support plate showing flow slot hour glassing and cracking between the flow slot and the first row of tubes.

Steam Generator 23, support plates 3 and 4
Indian Point 2.



Cracked support plate

Steam Generator 22, support plate 1
Indian Point 2

ATTACHMENT D

Photograph of Wrapper and Tube Support Plate Annulus

Steam Generator No. 24

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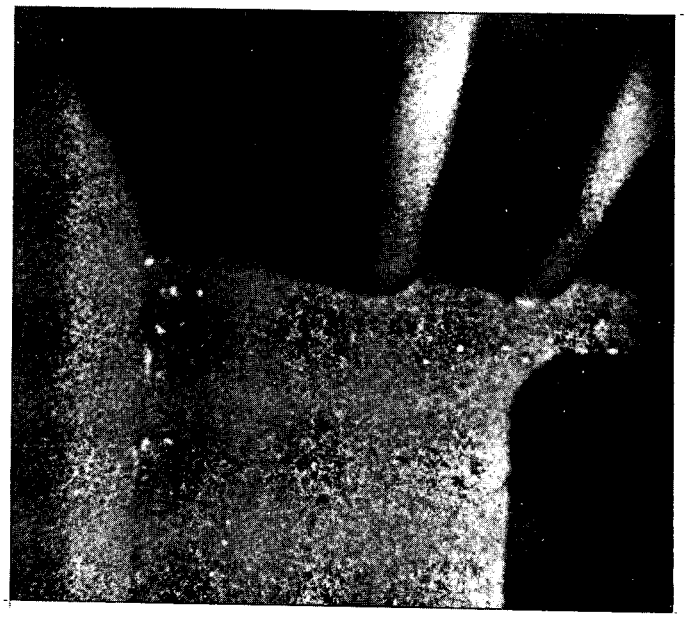
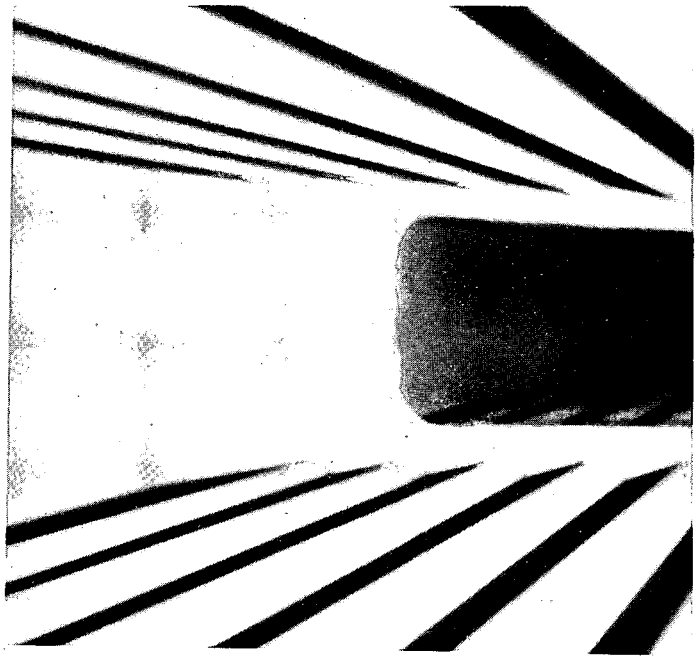


March, 1978



July, 1979

Wrapper and tube support plate

Steam Generator 24, Support plate 1, manway side
Indian Point 2.

ATTACHMENT E

Steam Generator Sludge Analysis

July 1979 Inspection

Consolidated Edison Company of New York, Inc.

Indian Point Unit No. 2
Docket No. 50-247
Facility Operating License No. DPR-26
August, 1979

Sludge Sample From Indian Point

Unit No. 2 Steam Generators

Sample No. 1

Petrographic Analysis

Fe_3O_4 - 70-80%
Fe_2O_3 - 1-10%
Cu (metal) - 5-15%
Cu as CuO - 1-10%
SiO_2 amorphous - Trace
SiO_2 quartz - Trace
$Ca_3(PO_4)_2$ - 1-10%

Quantitative Analysis

Fe as Fe_3O_4 - 83.5%
Cu as Cu - 15.2%
Ni as Ni - 1.2%
Zn as Zn - 1.5%
Boron as B - <0.5%
Na as Na - 0.1%

Quantitative Anions

Sulfates - Not Detected
Chlorides - 0.12% Cl
Phosphates (H_2O sol) <0.2% PO_4
Phosphates (H_2O insol.) 6.7% PO_4

Spectrographic Analysis

Fe $\gg$10%
Cu >10%
Zn >1
Ni $\approx$1
Mn $\approx$0.1
Al <0.1
Si <0.1
Cr <0.1
Sn <0.1
Pb <0.1
Mg <0.1
Ca <0.1
Na <0.1
Ti <0.1
Ag <0.1

Note: Samples were dried at 110°C prior to analysis.

Sludge Sample From Indian Point

Unit No. 2 Steam Generators

Sample No. 2

Petrographic Analysis

Fe as Fe_3O_4	- 65-75%
Fe_2O_3	- 1-10%
Cu (metal)	- 5-15%
Cu as CuO	- 1-10%
SiO_2 (amorphous)	1-5%
SiO_2 (quartz)	Trace
$Ca_3(PO_4)_2$	- 1-10%

Spectrographic Analysis

Fe	$\gg$10%
Cu	>10%
Ni	$\approx$1
Zn	>1
Al	<0.1
Si	<0.1
Cr	<0.1
Sn	<0.1
Pb	<0.1
Mn	<0.1
Mg	<0.1
Ca	<0.1
Na	<0.1
Ti	<0.1
Ag	<0.1

Quantitative Analysis

Fe as Fe_3O_4	- 74.1%
Cu as Cu	- 17.4%
Ni as Ni	- 0.8%
Zn as Zn	- 2.1%
B as B	- <0.5%
Na as Na_2O	- 0.1%

Quantitative Anions

Sulfates	- Not Detected
Chlorides	- 0.12% Cl
Phosphates	- (H_2O sol.) <0.2% PO_4
Phosphates	- (H_2O insol.) 4.8% PO_4

Sludge Sample From Indian Point

Unit No. 2 Steam Generators

Sample No. 3

Petrographic Analysis

Fe_3O_4 - 60-70%
Fe_2O_3 - 1-10%
Cu (metal) - 10-20%
Cu as CuO - 1-10%
SiO_2 amorphous - 1-10%
SiO_2 quartz - Trace
$Ca_3(PO_4)_2$ - 1-10%

Spectrographic Analysis

Fe >>10%
Cu >10%
Zn >1
Al 0.1-1
Ni ≈1
Si <0.1
Cr <0.1
Sn <0.1
Pb <0.1
Mg <0.1
Ca <0.1
Na <0.1
Ti <0.1
Ag <0.1

Quantative Analysis

Fe as Fe_3O_4 - 71.6%
Cu as Cu - 22.3%
Ni as Ni - 1.1%
Zn as Zn - 2.0%
B as B - <0.5%
Na as Na - 0.2%

Quantitative Anions

Sulfates - Not detected
Chlorides - 0.12% Cl
Phosphates - (H_2O sol.) <0.2% PO_4
Phosphates - (H_2O insol.) 6.2% PO_4

Sludge Sample From Indian Point

Unit No. 2 Steam Generators

Sample No. 4

Petrographic Analysis

Fe_3O_4 - 60-70%
Fe_2O_3 - 1-10%
Cu (metal) - 5-25%
Cu as CuO - 1-10%
SiO_2 (amorphous) - 1-5%
SiO_2 (quartz) - Trace
$Ca_3(PO_4)_2$ - 1-10%

Spectrographic Analysis

Fe	≫10%
Cu	≫10%
Zn	>1
Al	0.1-1
Ni	≈1
Si	0.1-1
Mn	0.1-1
Cr	<0.1
Sn	<0.1
Pb	<0.1
Mg	<0.1
Ca	<0.1
Na	<0.1
Ti	<0.1
Ag	<0.1

Quantitative Analysis

Fe as Fe_3O_4	- 68.8%
Cu as Cu	- 22.8%
Ni as Ni	- 1.3%
Zn as Zn	- 2.3%
B as B	- <0.5%
Na as Na_2O	- 0.15%

Quantitative Anions

Sulfates - Not detected
Chlorides - 0.12%
Phosphates - (H_2O sol.) <0.2% PO_4
Phosphates - (H_2O insol.) 5.5% PO_4

Sludge Sample From Indian Point

Unit No. 2 Steam Generators

Sample No. 5

Petrographic Analysis

Fe_3O_4 - 55-65%
Fe_2O_3 - 1-10%
Cu (metal) - 15-25%
Cu as CuO - 1-10%
SiO_2 (amorphous) 1-10%
SiO_2 (quartz) - Trace
$Ca_3(PO_4)_2$ - 1-10%

Spectrographic Analysis

Fe $\gg$10%
Cu $\gg$10%
Zn >1
Ni $\approx$1
Mn 0.1-1
Al <0.1
Si <0.1
Cr <0.1
Sn <0.1
Pb <0.1
Mg <0.1
Ca <0.1
Na <0.1
Ti <0.1
Ag <0.1

Quantitative Analysis

Fe as Fe_3O_4 - 70.3%
Cu as Cu - 21.8%
Ni as Ni - 1.2%
Zn as Zn - 2.5%
B as B - <0.5%
Na as Na - 0.1%

Quantitative Anions

Sulfates - Not detected
Chlorides - 0.08% Cl
Phosphates - (H_2O sol.) <0.2% PO_4
Phosphates - (H_2O insol.) 2.3% PO_4

Sludge Sample From Indian Point

Unit No. 2 Steam Generators

Sample No. 6

Petrographic Analysis

Fe_3O_4 - 40-50%
Fe_2O_3 - 1-10%
Cu(metal) - 30-40%
Cu as CuO - 1-10%
SiO_2(amorphous) - 1-10%
SiO_2(quartz) - Trace
$Ca_3(PO_4)_2$ - 1-10%

Spectrographic Analysis

Fe $\gg$10%
Cu $\gg$10
Zn >1
Al 0.1-1
Ni $\approx$1
Cr 0.1-1
Mn 0.1-1
Sn <0.1
Pb <0.1
Mg <0.1
Ca <0.1
Na <0.1
Ti <0.1
Ag <0.1

Quantitative Analysis

Fe as Fe_3O_4 - 51.3%
Cu as Cu - 38.6%
Ni as Ni - 1.4%
Zn as Zn - 2.4%
B as B - <0.5%
Na as NA - 0.1%

Quantitative Anions

Sulfates - Not detected
Chlorides - 0.12% Cl
Phosphates - (H_2O sol.) <0.2% PO_4
Phosphates - (H_2O insol.) 4.0% PO_4

Sludge Sample From Indian Point

Unit No. 2 Steam Generators

Sample No. 7

Petrographic Analysis

Fe_3O_4 - 45-55%
Fe_2O_3 - 1-10%
Cu (metal) - 30-40%
Cu as CuO - 1-10%
SiO_2 (amorphous) - 1-5%
SiO_2 (quartz) - Trace
$Ca_3(PO_4)_2$

Spectrographic Analysis

Fe	>>10%
Cu	>>10
Zn	> 1
Al	0.1-1
Ni	≈ 1
Mn	0.1-1
Si	< 0.1
Cr	< 0.1
Sn	< 0.1
Pb	< 0.1
Mg	< 0.1
Ca	< 0.1
Na	< 0.1
Ti	< 0.1
Ag	< 0.1

Quantitative Analysis

Fe as Fe_3O_4	- 52.9%
Cu as Cu	- 37.0%
Ni as Ni	- 1.6%
Zn as Zn	- 3.2%
B as B	- <0.5%
Na as Na_2O	- 0.1%

Quantitative Anions

Sulfates - Not detected
Chlorides - 0.09% Cl
Phosphates - (H_2O sol.)<0.2% PO_4
Phosphates - (H_2O insol.) 5.3% PO_4