Con Edison
Consolidated Edison Company of New York, Inc.
Indian Point Station
Broadway & Bleakley Avenue
Buchanan, New York 10511-1099

December 17, 1987

Re: Indian Point Unit No.2
Docket No. 50-247

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Susceptibility of Indian Point Unit No. 2 (IP-2) Steam Generators to High Cycle Fatigue Tube Failure

This letter transmits a summary of the evaluation of Indian Point Unit No. 2 (IP-2) U-bend tubing for susceptibility to a fatigue failure of the type experienced at North Anna 1 on July 15, 1987. Our November 23, 1987 letter provided our completed evaluation regarding steam generators 22 and 24 and indicated that similar analyses for steam generators 21 and 23 would be performed after anti-vibration bars (AVB) insertion depths are verified for these generators by analyzing eddy current data taken during the current refueling outage. The AVB insertion depths are a key factor in the assessment of fatigue failure susceptibility.

The IP-2 eddy current (EC) testing program was recently completed and a review of the EC measurements for steam generators 21 and 23 verified AVB position for all tubes except two due to copper deposit interference. These two tubes, R12C89 and R12C90 in steam generator 21, were preventively plugged to eliminate them from further consideration. All remaining tubes were shown to have relative stability ratios less than 0.9 and stress ratios less than 1.0, thereby meeting the established criteria for determining that there is no need for further corrective action.

Attachment A presents our evaluation of fatigue susceptibility of U-bend tubes for all four steam generators. Based on this evaluation, it is concluded that the IP-2 tubes remaining in service are not expected to be susceptible to fatigue rupture at the top support plate in a manner similar to that which occurred at North Anna 1. Therefore, no additional modification, preventive tube plugging or other measure to preclude such an event is judged to be necessary.

Please contact us if you have any questions on this matter.

Very truly yours,

Vice President
Nuclear Power

Attachment

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PDR ADOCK 05000247
P DCD

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ATTACHMENT A

Evaluation of Dented Tube Fatigue Susceptibility
At Indian Point Unit 2

Consolidated Edison Company of New York, Inc.
Indian Point Unit No. 2
Docket No. 50-247
December, 1987

EVALUATION OF DENTED TUBE FATIGUE SUSCEPTIBILITY AT INDIAN POINT UNIT 2

INTRODUCTION

The Indian Point 2 steam generators have been evaluated for the susceptibility of unsupported U-bend tubing with denting at the top tube support plate to a fatigue rupture of the type experienced at Row 9 Column 51 (R9C51) of Steam Generator C, North Anna 1.

BACKGROUND

The initiation of the circumferential crack in the tube at the top of the top tube support plate at North Anna 1 was due to limited displacement, fluid elastic instability. The unstable condition prevailed in the R9C51 tube when the tube experienced denting at the support plate. A combination of conditions were present that led to the rupture. The tube is not supported by an anti-vibration bar (AVB), has a higher flow field due to the uneven insertion depths of AVB's, has reduced damping because of denting at the top support plate, and has reduced fatigue properties because of the additional mean stress with the denting and in the presence of the all volatile treatment (AVT) chemistry of the secondary water.

CRITERIA FOR EVALUATION

The criteria established for determining the benefit of ameliorative action was a 10% reduction in stability ratio that is expected to provide a 58% reduction in stress amplitude (to $<$4.0 ksi) for a Row 9 tube in the North Anna 1 steam generators. This reduction is expected to reduce the future fatigue usage to $<$0.021 per year for a Row 9 tube and to preclude growth of an existing through wall crack of up to 0.125 inch in length. This same criterion has been used as one of several criteria in the evaluation of Indian Point 2 tubing. With additional effects accounted for through a stress ratio criteria that permits the calculation of fatigue usage to demonstrate tube acceptability, the final criteria of cumulative fatigue usage to date plus future operation with current operating parameters has to be satisfied.

The stability ratios for Indian Point 2 tubing, the corresponding stress amplitude, and the resulting cumulative fatigue usage must be evaluated relative to the ruptured tube at Row 9 Column 51, North Anna 1, Steam Generator C, for two reasons. First, the local effect on the flow field due to various AVB insertion depths is not within the capability of available analysis techniques and must be determined by test. Second, an analysis and examination of the ruptured tube provided a range of initiating stress amplitudes but can only bound the possible stability ratios that correspond to these stress amplitudes. Therefore, the evaluation of Indian Point 2 tubing has been based on relative stability ratios, relative flow peaking factors and stress ratios.

The determination of stability ratio is the evaluation of a ratio of velocities, the effective velocity divided by the critical velocity. A value greater than unity (1.0) indicates instability. The stress ratio is the expected stress amplitude in an Indian Point 2 tube divided by the stress amplitude responsible for the North Anna 1 tube rupture.

The criteria for establishing that a tube has support from an AVB which eliminates it from further consideration is that at least one sided support is present to at least the tube centerline. This has been established by analysis of eddy current (EC) measurements by either an EC indication of both legs of the AVB or by projecting the depth of insertion knowing the geometry of the AVB and EC indications that locate it on at least three larger radius U-bends in the same column of tubes.

Results of Evaluation

The AVB insertion depths are a key factor in the assessment of fatigue failure susceptibility since the AVB positions determine the local flow peaking factors. The local flow peaking factor is a direct multiplier on the stability ratio and a small percentage change causes a significant change in stress amplitude. The relative flow peaking factors for Indian Point 2 tubing without direct AVB support have been determined by instability tests. These factors have been applied to relative stability ratios determined by 3-D tube bundle flow analysis and the combined relative stability ratio used in the stress ratio determination.

The analysis of eddy current (EC) measurements shows that denting of some tubes is present at the top support plate and therefore all of the tubes in Rows 8 to 12 are treated as dented. The effect of denting on the fatigue life of the tube has been conservatively maximized by assuming the maximum effect of mean stress (based on 55 ksi) in the tube fatigue usage evaluation and by incorporating reduced damping in the tube vibration evaluation. A partial review of EC measurements also shows that none of the reviewed tubes in Row 8 through 12 have wall thinning indications at the AVB locations. Therefore, it is unlikely that those tubes have been unstable. Additionally, the eddy current data have been used to define AVB insertion depths and the extent of tube support for each column of tubes within the region. As shown in Figures 1,2,3 and 4, virtually all row 12 tubes are supported except for a few peripheral columns. Most row 11 and row 10 tubes are supported. Some row 9 and row 8 tubes are supported. Twenth-eight tubes (not including symmetrical tube locations) are identified as unsupported and dented tubes with the highest potential for fluid elastic vibration. These tubes are listed in Table 1. The local flow peaking corresponding to the AVB insertion depth near each of these tubes has been factored into the evaluation for each of these tubes. The results of incorporating local flow peaking is shown in Table 2 in the relative stability ratios presented. Stress ratios are also presented in Table 2 for each of the tubes in Table 1. With the exception of two tubes in steam generator 21, all tubes have relative stability ratios less than 0.9 and stress ratios less than 1.0. The two tubes exceeding these criteria are R12C89 and R12C90 in steam generator 21. These two tubes have been plugged as a preventive measure to eliminate them from further consideration.

Of the remaining tubes that meet the criterion, the tube at R11C47 has the highest stress ratio, 0.75. The expected maximum stress ampltiude for this tube is 3.0 ksi. Based on the operating history of Indian Point Unit 2, which is presented in Figure 5 in the form of normalized stability ratio versus time in days, the fatigue usage to date is expected to be less than 0.046. Projecting this to 40 years total operation, the fatigue usage is expected to be less than 0.114. This is less than the ASME Code limit of 1.0. The fatigue usage calculation utilizes a lower bound fatigue curve that is consistent with the fatigue properties of the North Anna tube that ruptured.

CONCLUSION

Based on these evaluations, it is concluded that the Indian Point 2 tubes remaining in service are not expected to be susceptible to fatigue rupture at the top support plate in a manner similar to that which occurred at North Anna 1. Therefore, no additional modification, preventive tube plugging or other measure to preclude such an event is judged to be necessary.

TABLE 1

UNSUPPORTED AND DENTED TUBES WITH THE HIGHEST VIBRATION DISPLACEMENT POTENTIAL

Steam Generator	Row	Column
21	10	3
		16
		24
		62
	11	3
		4
		86
		87
		88
		89
	12	2
		89
		90
22	10	24
	11	3
		37
	12	2
23	10	3
		20
	11	2
		3
		4
		47
24	10	71
	11	3
		46
		51
	12	2

TABLE 2

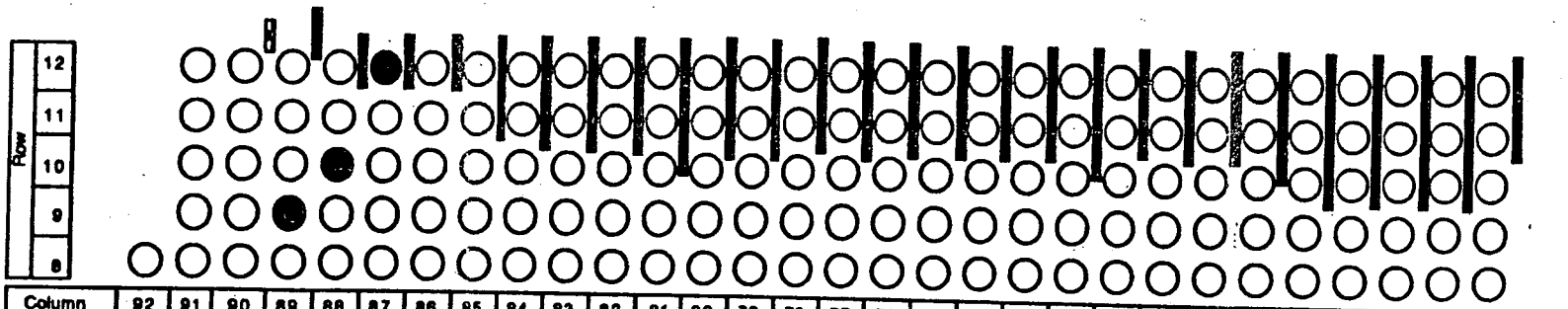
RESULTS OF EVALUATION OF UNSUPPORTED AND DENTED TUBES WITH THE HIGHEST VIBRATION DISPLACEMENT POTENTIAL

Steam Generator	Tube	Relative Stability Ratio(1)	Stress Ratio(1)
21	R10C3	0.70	0.21
	R10C16	0.68	0.19
	R10C24	0.74	0.31
	R10C62	0.75	0.33
	R11C3	0.84	0.55
	R11C4	0.82	0.50
	R11C86	0.77	0.34
	R11C87	0.79	0.40
	R11C88	0.81	0.45
	R11C89	0.82	0.50
	R12C2	0.79	0.35
	R12C89	1.10	>1.0(2)
	R12C90	1.14	>1.0(2)
22	R10C24	0.68	0.19
	R11C3	0.84	0.55
	R11C37	0.73	0.25
	R12C2	0.79	0.35
23	R10C3	0.70	0.21
	R10C20	0.74	0.31
	R11C2	0.58	0.06
	R11C3	0.84	0.55
	R11C4	0.82	0.50
	R11C47	0.88	0.75
24	R10C71	0.73	0.29
	R11C3	0.84	0.55
	R11C46	0.84	0.58
	R11C51	0.74	0.27
	R12C2	0.79	0.35

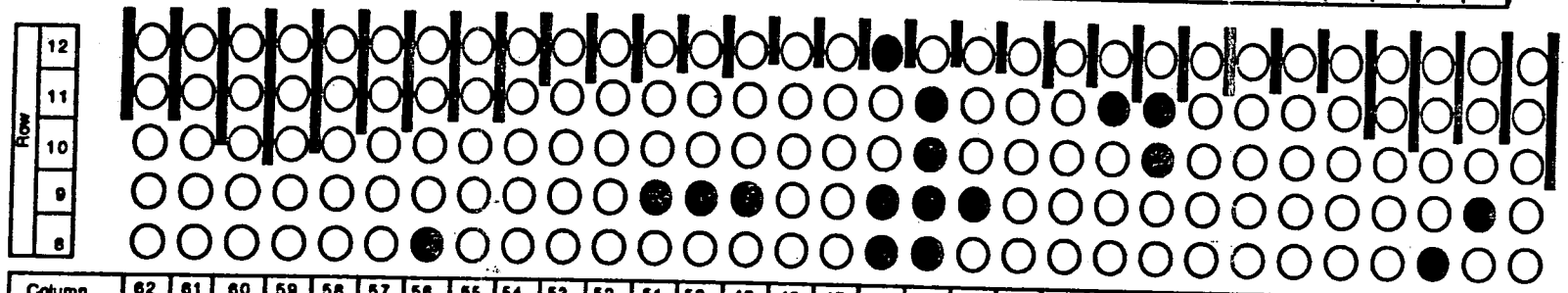
(1) All ratios are in comparison to R9C51, North Anna 1, Steam Generator C.

(2) This tube has been plugged as a preventive measure.

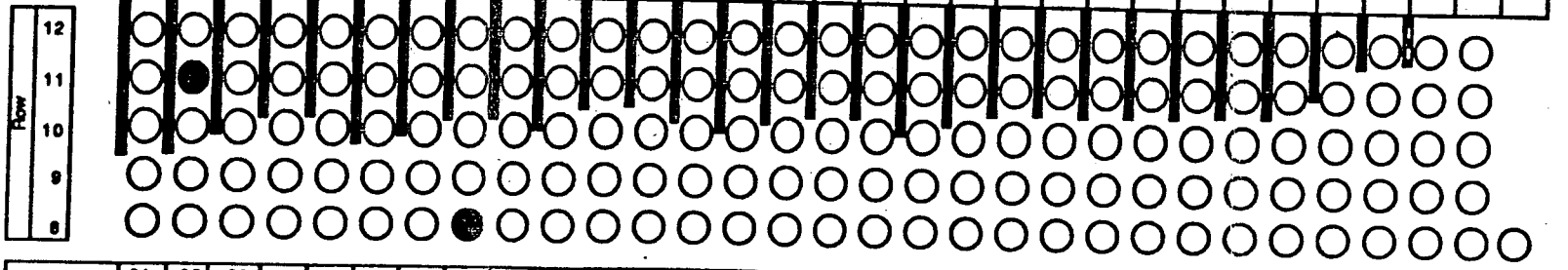
Indian Point -2: S/G -21
AVB Positions



Column	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63
Projection				12.7	11.8	11.7	11.7	10.9	10.5	10.3	10.2	10.2	10	10.3	10.3	10.4	10.2	10.2	10.3	10.3	10	10.2	10.4	10.3	10.1	9.6	9.6	9.6	9.6	9.5
L1																														



Column	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32
Projection	10.6	10.1	9.7	10	10.1	10.2	10.5	10.6	10.8	11.2	11.3	11.5	11.4	11.8	11.9	11.9	11.9	11.9	11.8	11.5	11.5	11.2	11.2	11.2	11.3	11.4	10.5	10.2	10.4	10.4	9.6
L1																															



Column	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Projection	9.4	9.5	10	10.2	9.9	9.8	10	10.2	10.2	10.1	10.4	10.5	10.2	10.	10.2	10.3	10.1	10.1	10.2	10.5	10.5	10.4	10.4	10.5	10.5	10.6	11	11.7	11.7		
L1																															

NOTES:
Projections are based on AVB centerline relative to tube centerline.
Column 3 and 89 AVB projections are based on single data points; not verified.

● Plugged Tube

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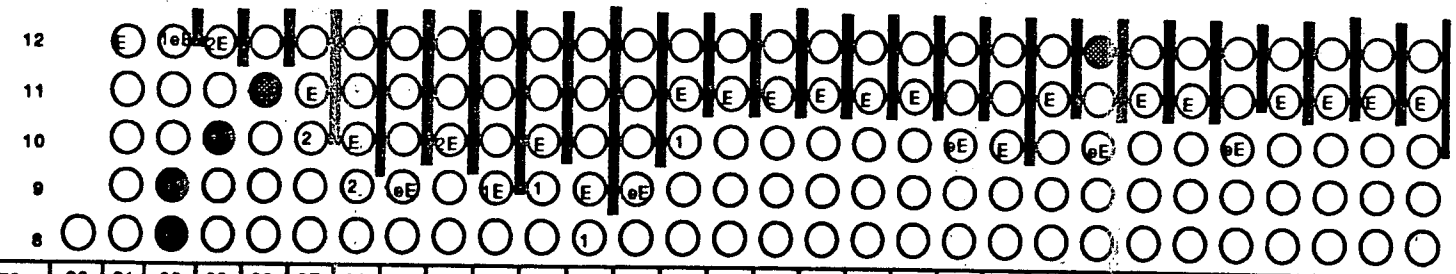
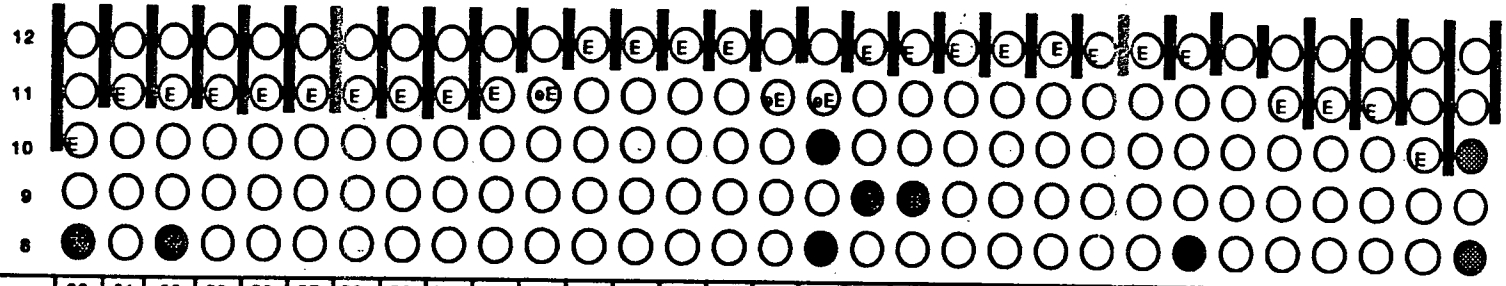
FIGURE 1

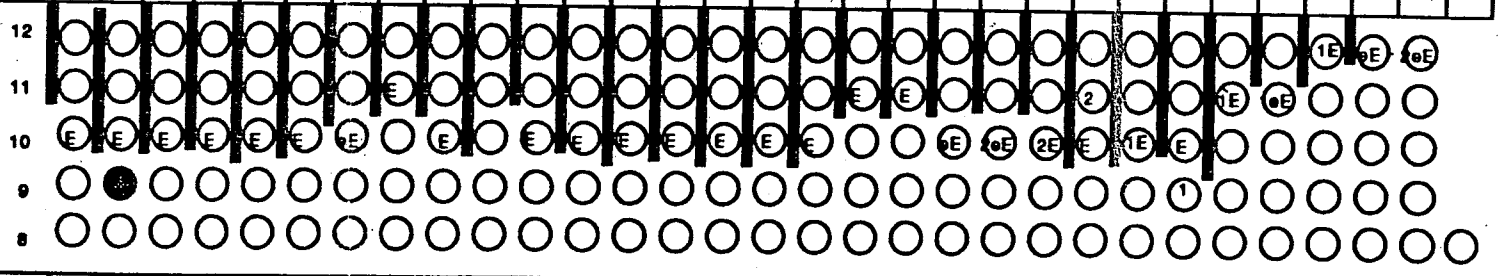
Indian Point - 2 : S/G - 22
AVB Insertion



Column	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63
Projection			12.1		11.6			10.5					10.3							10.6			10.6			11				
L1			2.8		1.8			1.1		2.5	2.3	7.5	.9	3.2																



Column	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32
Projection										1.7	1.6					11.8	11.4			11.8						11.6					10.8
L1																															



Column	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Projection	11.1						10.7			10.8										10.8	10.8						12		12.1		
L1																								3.6	1.4	1.8	0.9	4.0			

NOTES:

E - EPRI calls of last tube with observable AVB indication

e - EPRI calls of AVB contacts ≤ 2.0 inches

Numbers in tubes refer to Westinghouse interpretation of AVBs visible

L1 - length of single AVB contacts read by Westinghouse

Projections by Westinghouse

Plugged Tube

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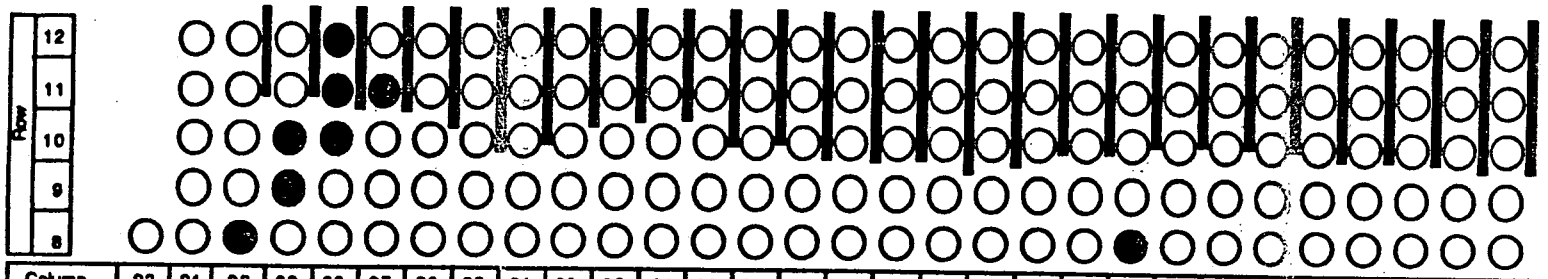
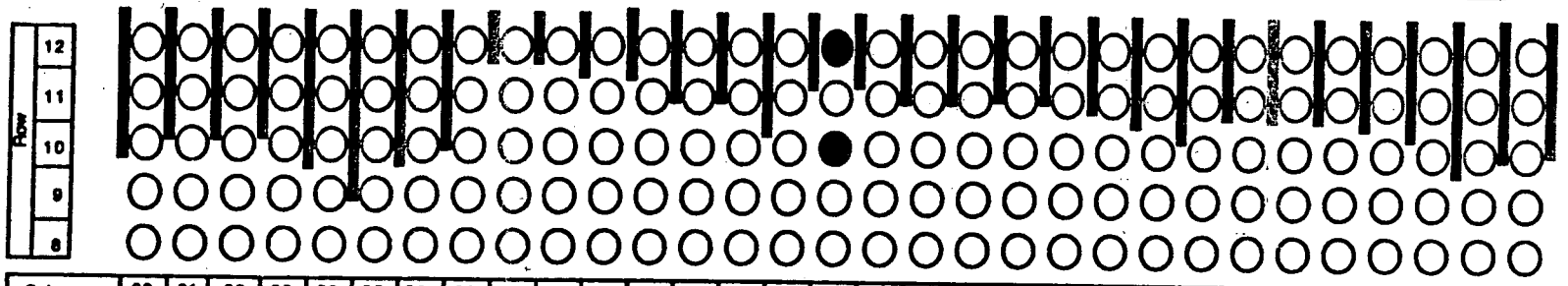
FIGURE 2

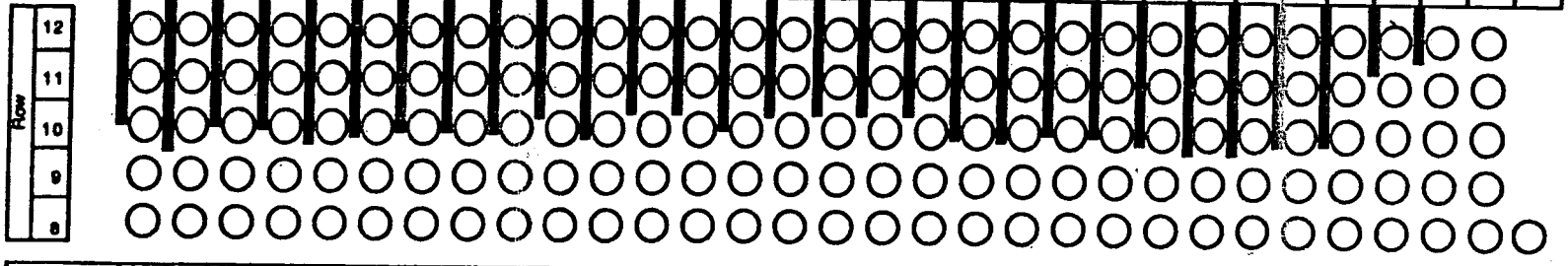
Indian Point - 2: S/G - 23
AVB Positions



Column	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63
Projection			11	11	10.7	10.5	10.2	9.9	9.8	10	10.3	10.4	10.1	10.1	9.8	9.7	9.7	9.3	9.5	9.9	9.9	9.9	10	10	10	9.9	9.8	9.8	9.5	9.6
L1																														



Column	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32
Projection	9.6	10	9.9	9.3	8.8	8.9	9.3	9.8	1.7	11.2	11.2	11.1	11	10.2	10.2	11.2	11	11	11	11	10.9	10.9	10.6	10.2	10.8	10.8	10.5	10.3	9.7	9.9	10
L1																															



Column	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Projection	9.8	9.8	10	9.9	9.8	9.9	10.1	10.1	10	10.2	10	10.4	10.1	10.1	10.3	10.4	10.4	10	9.9	9.9	10	9.9	9.7	9.6	9.7	9.9	9.9	11.3	11.6		
L1																															

NOTES
Projections are based AVB centerline relative to tube centerline.

● Plugged Tube

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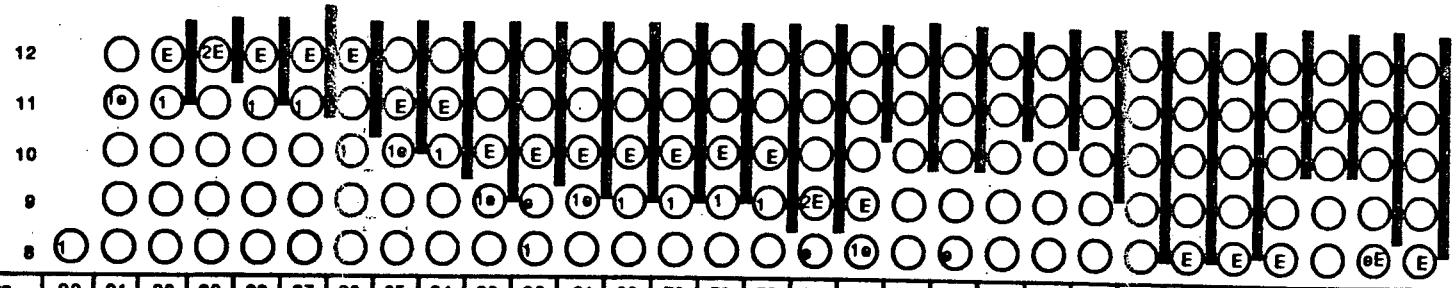
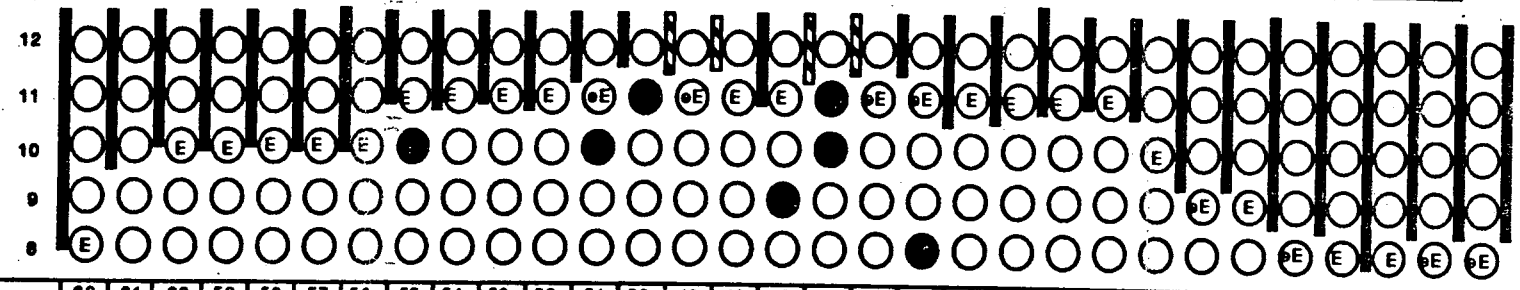
FIGURE 3

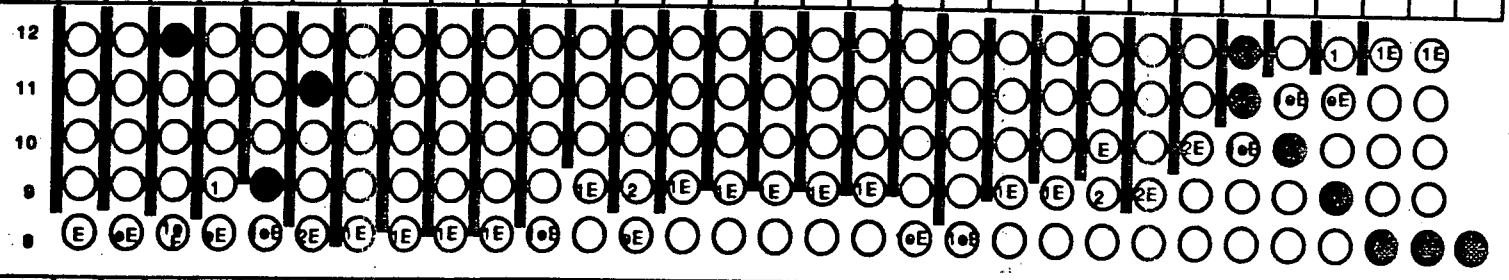
Indian Point - 2 : S/G -24
AVB Insertion



Column	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63
Projection								11.1		10.3	10.9	11.7					10.4	10.1	10.2	9.9	9.8	10.5	10.3	9.3				9.7	10.9	
L1	2.0	1.0	3.9		3.7	4.5	1.2	3.5	4.6	2.6	0.8	2.5	2.4	3.0	3.3	4.8		2.4												



Column	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32
Projection		9.5								11.		12	12						10.4	10.7					11.7		9.9			10.7	11
L1																															



Column	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Projection		10.7	10.2	11.1	11.3						10.7		10.4						10.6	11						11.5	11.7		11.6		
L1			1.0	2.7	1.7		2.9	2.2	3.2	3.2	2.0	1.9		1.5	2.0	2.5	3.2	3.1	1.1	1.6	4.0	2.0				1.9	1.2	2.3	1.6	1.4	

NOTES:

- e - EPRI calls of AVB contacts ≤ 2.0 inches
- E - EPRI call of last tube with observable AVB indication
- Numbers in tubes refer to Westinghouse interpretation of AVBs visible
- L1 - length of single AVB contacts read by Westinghouse
- Projections by Westinghouse
- Indications in Columns 2 and 92 are retainer rings

● Plugged Tube

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FIGURE 4

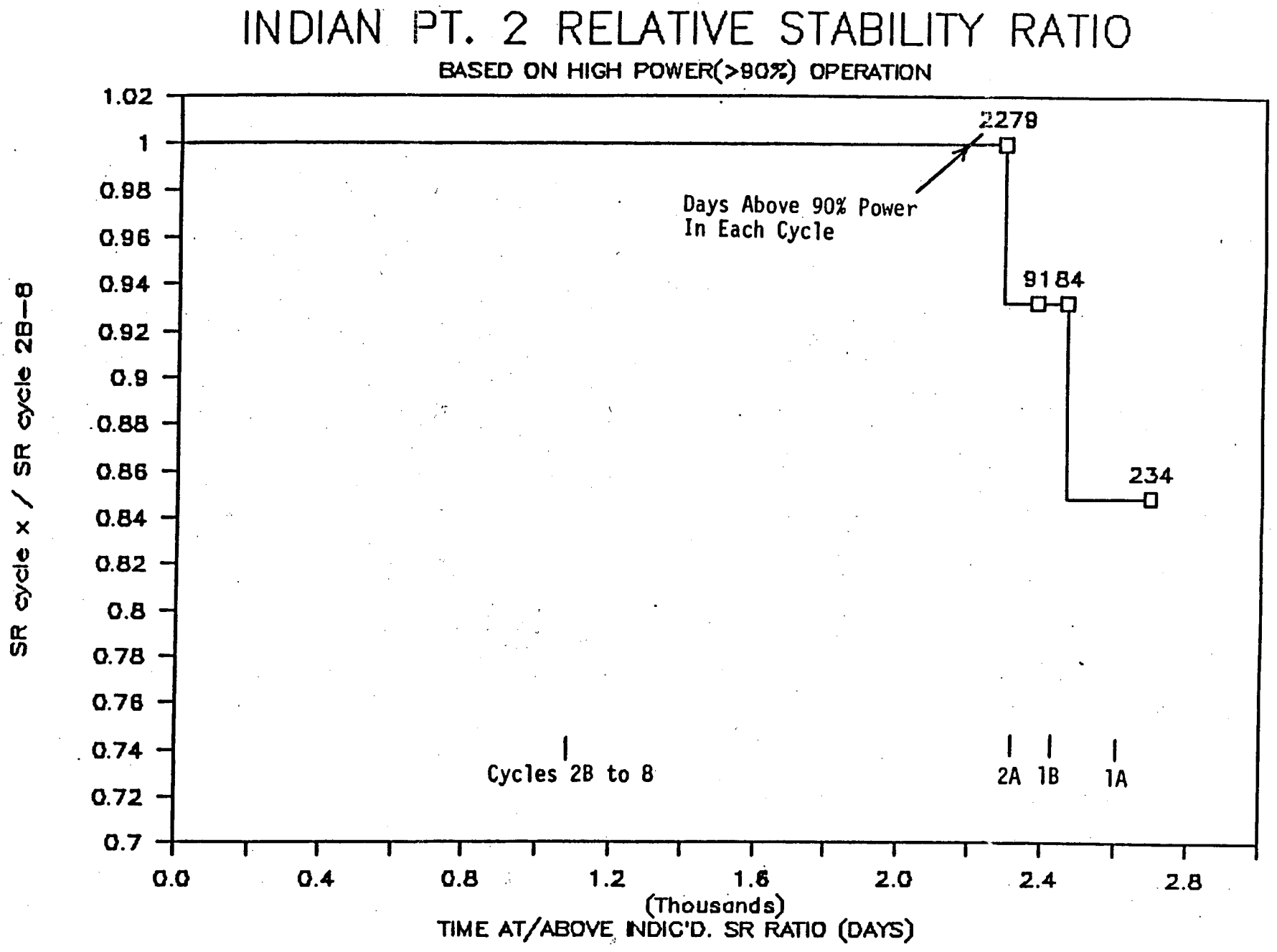
INDIAN PT. 2 RELATIVE STABILITY RATIO
BASED ON HIGH POWER(>90%) OPERATION
SR cycle x / SR cycle 2B-8
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0.78
0.76
0.74
0.72
0.7
2279
Days Above 90% Power
In Each Cycle
9184
234
Cycles 2B to 8
2A
1B
1A
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
(Thousands)
TIME AT/ABOVE INDIC'D. SR RATIO (DAYS)

FIGURE 5