Georgia Power Company
333 Piedmont Avenue
Atlanta, Georgia 30308
Telephone 404 526-7726

Mailing Address:
Post Office Box 4545
Atlanta, Georgia 30302

Georgia Power
the southern electric system

D. O. Foster
Vice President and General Manager
Vogtle Project

May 25, 1984

Director of Nuclear Reactor Regulation
Attention: Ms. Elinor G. Adensam, Chief
Licensing Branch #4
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

File: X7BC35
Log: GN-360

NRC DOCKET NUMBERS 50-424 AND 50-425
CONSTRUCTION PERMIT NUMBERS CPPR-108 AND CPPR-109
VOGTLE ELECTRIC GENERATING PLANT - UNITS 1 AND 2
REQUEST FOR ADDITIONAL INFORMATION - SUPPLEMENTAL
INFORMATION TO ER-OL AMENDMENT 3

Dear Mr. Denton:

In Ms. Adensam's letter dated April 17, 1984, requests were made for supplemental information which is not part of the ER-OL. This material is being sent as enclosures to this letter. Attached is a listing of the enclosures being provided.

If you have any questions concerning the enclosed information, do not hesitate to contact us.

Yours truly,

D.O. Foster

D. O. Foster

DOF/KWK/sw
Enclosure
xc: M. A. Miller
R. A. Thomas
J. A. Bailey
O. Batum
L. T. Gucwa
G. F. Trowbridge, Esquire
G. Bockhold, Jr.
D. G. Eisenhut

H001
1/5

ADD: EHEB 4C43
PM LTR ONLY

DIST PER M. MILLER

SUPPLEMENTAL MATERIAL: AMENDMENT 3 TO THE ER-OL

NRC QUESTION #	MATERIAL	# COPIES
E290.13	"Sound level study at the Alvin W. Vogtle Nuclear Plant Site Prior to Construction" by C. E. Hickman, Southern Company Services, Inc. 1974.	6
	"Construction Sound Level Survey, Alvin W. Vogtle Nuclear Plant" by C. E. Hickman and H. A. Feariug, Southern Company Services, Inc. May 1981.	6
E290.14	"Sound Level Study, Miller Arkadelphia 500 KV Transmission Line Study" Southern Company Services.	6
E290.15	"Cooling Tower Noise" Southern Company Services.	6

GEORGIA POWER COMPANY
ALVIN W. VOGTLE NUCLEAR PLANT

SOUND LEVEL STUDY AT THE ALVIN W. VOGTLE NUCLEAR PLANT SITE PRIOR TO CONSTRUCTION

Research Department
SOUTHERN SERVICES, INC.
Birmingham, Alabama

SOUND LEVEL STUDY AT THE ALVIN W. VOGTLE NUCLEAR PLANT SITE PRIOR TO CONSTRUCTION

INTRODUCTION

A Sound level study was performed at the Alvin W. Vogtle Nuclear Plant site on May 14-15, 1974. Results of the survey are presented in the following formats.

1. Nine pages of Noise Survey Forms
2. Chart recordings of sound level as a function of time.

Location of the measurements are noted on the Site Plot Plan, Figure 2.1-3 of the Environmental Report and on sketches on the Noise Survey Forms.

RESULTS

a. Ambient Sound Levels

The main purpose of the survey was to ascertain noise levels prior to the beginning of construction of the nuclear units. A significant number of measurements, tabulated on pages 1 and 2 of the Noise Survey Forms, were taken during the evening hours of May 14, 1974. Sound levels ranged from 22-39 dBA with most readings falling in the 25-30 dBA range. Under calm wind conditions the sound level fell to 22 dBA but increased to 34 dBA when the wind gusted to 7 mph. The large increase was due primarily to rustling leaves. The 39 dBA reading occurred at the South fence line of the combustion turbine plant and the main contributors were the transformers since no combustion turbines were operating.

Other noise sources at the observation points were a number of singing birds and other night life sounds.

As a matter of interest it was noted that passing traffic produced sound levels of 80-88 dBA at positions along the road bounding the western and southern property lines.

Pages 2 and 3 of the Noise Survey Forms indicate that sound levels of 28-44 dBA were measured around the site during the following morning. The highest noise level of 44 dBA occurred during wind gusts of up to 10 mph. Generally, wooded areas, such as the proposed intake structure area, had higher sound levels due to the wind in the trees.

A magnetic tape recording was made at the N80+00, E81+00 location and the resulting sound levels as a function of time are plotted on Figures 1 and 2.

Figure 1 indicates that the dBA sound level, in general, varied from 25-30 dBA at the N80+00, E81+00 position. The sharp peaks on the graph are the result of bird calls such as whippoorwills. The dB linear sound levels as shown on Figure 2 range from 35-45 dB. A fuel truck at the combustion turbine plant increased the sound level to above 50 dB linear.

A comparison of Figures 1 and 2 indicates the following.

(1) The A-weighted sound levels are approximately 10 dB lower than the dB linear sound levels.

(2) Peaks in the A-weighted response due to high frequency bird calls are more pronounced since the low frequencies (<1000Hz) in the sound level spectrum are attenuated by the weighting network.

(3) Truck noise has less effect on the A-weighted response since it is predominantly low frequency.

b. Transformer Sound Levels

Sound levels produced by large transformers presently at the combustion turbine site were also measured and the results are tabulated on pages 4 and 5 of the Noise Survey Forms. At 3' from the transformers the sound levels were 79-80 dBA with the predominant frequency being 125Hz. Although the effect on the dBA sound level was minimal at a position such as N80+00 where a magnetic tape recording was made, the 125Hz tone was clearly audible. This position is approximately one mile from the transformers. During the above tests none of the combustion turbines were operating.

c. Sound Levels Around Combustion Turbines

Sound level measurements were taken around combustion turbine 5E at 3' distances from major components. These data plus additional measurements associated with the combustion turbines are tabulated on pages 6-9 of the Noise Survey Forms.

The levels obtained around combustion turbine 5E ranged from 81 dBA 3' East of the turbine to 92 dBA near the generator and exciter.

Rather high noise levels were observed inside the enclosure, e.g., 105 dBA at the turbine, 114 dBA at the generator intake and 116 dBA at the bearing compartment between the turbine and generator. The sound level was 94-96 dBA on the turbine platform and 93 dBA at the exciter view window.

Midway between two operating combustion turbines (5D and 5E) the sound level was 82 dBA.

The decrease in the sound level as a function of distance from 100' to 2000' from the combustion turbines is noted on page 8 of the Noise Survey Forms. The 6 dB decrease for each doubling of distance rule for this situation is quite closely achieved.

SUMMARY

This report is the first of a number concerned with sound levels at the Alvin W. Vogtle Nuclear Plant site. The main concern of this study was the determination of sound levels prior to construction. A second study will focus on construction noise and a third will contain predictions of sound levels during operation. Finally, actual operating sound levels will be measured.

To fulfill one of the provisions of the Noise Control Act of 1972, the Environmental Protection Agency has published the document "Information on Levels of Environmental Noise Requisite To Protect Public Health and Welfare With An Adequate Margin of Safety." The recommendation for environmental noise in the above document is a day-night average L_{dn}=55 dB. This sound level is equivalent to 49 dBA.

As indicated in this report sound levels measured at the property lines prior to the beginning of construction of the nuclear units are below the recommended value of the Environmental Protection Agency.

NOISE SURVEY FORM

SOUTHERN SERVICES INC
P.O. Box 2625
BIRMINGHAM, ALABAMA 352[illegible]

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/14/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
- SLM: TYPE B&K 2209 SER. # 454249
- TRANSDUCER: TYPE B&K4145 SER. # 456988
- ANALYZER: TYPE B&K 1613 SER. # 460875
- CABLE: TYPE LENGTH
- CALIBRATOR: TYPE B&K 4220 SER. # 457476
- OTHER: Windscreen

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS: Ambient evening sound levels

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
18:10	OK	75			0-7	SSE

TEST NO.	TIME	POSITION*	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.								
						31.5	63	125	250	500	1000	2000	4000	8000
1	18:15	A	NW Corner of property	27-30										
2	18:22	B	N 111+00, E 15+00	25-30	35	28	30	26	27	30	30	20	15	10
3	18:35	C	N 60+00, E 37+00	25-34										
4	18:45	D	At Ebenezer Church Road	22-25	35	29	26	25	25	22	17	15	12	11
5	18:55	E	N 22+00, E 110+00	25										
6	19:05	F	N 60+00, E 143+00	39										
7	20:00	G	N 76+00, E 106+00	27										
8	20:10	H	N 76+00, E 115+00	28										

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "plant grid system." See site plot plan, Figure 2.1-3 of the Alvin W. Vogtle Nuclear Plant Environmental Report.

NOTES:
Position B - Birds increased sound level to 38 dBA
Position C - Passing traffic produced sound levels of 80-88 dBA.
Sound level of 34 dBA produced when wind gusted to 7mph
Position F - South fence at combustion turbine plant; sound level primarily due to transformers, no combustion turbines on

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 3520[illegible]

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/14/15/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen and Nagra tape recorder

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS: Ambient evening and morning sound levels. Three combustion turbines on after 10:00am

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
21:30	OK					
9:00	OK					

TEST NO.	TIME	POSITION*	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
			May 14, 1974											
9	20:25	I	N 80+00, E 81+00	28	40	30	29	36	32	20	20	20	22	20
			May 15, 1974											
10	9:30	I	N 80+00, E 81+00	28-38										
11	9:35	J	Borehole No. 620	≈34										
12	9:45	K	N 138+00, E 40+00	34										
13	9:55	L	N 105+00, E 20+00	34-44										
14	10:05	M	Tower 8, River Facility Rd	34-40										

SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms; OCTAVE BAND CENTER FREQUENCY, Hz.

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "plant grid system." See site plot plan, Figure 2.1-3 of the Alvin W. Vogtle Nuclear Plant Environmental Report

NOTES:
Positions I&J - Some drilling activity during AM but not PM
Positions L - Higher noise level of 44 dBA occurred during wind gusts of up to 10 mph.
Positions I - Magnetic tape recording made at 20:25.

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 3520[illegible]

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/15/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS: Ambient morning sound levels

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION*	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M^2 rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.								
						31.5	63	125	250	500	1000	2000	4000	8000
15	10:10	N	Dr. Brown's cabin	35-40										
16	10:25	O	Intake structure area	40-42										
17	10:35	P	N 80+00, E 117+00	34-40										
18	10:55	Q	N 80+00, E 113+00	35-40										

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "plant grid system." See site plot plan, Figure 2.1-3 of the Alvin W. Vogtle Nuclear Plant Environmental Report.

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC
P.O. Box 2625
BIRMINGHAM, ALABAMA 352[illegible]

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/14/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
SLM TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE B&K4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Transformers
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS: All of the combustion turbines were off

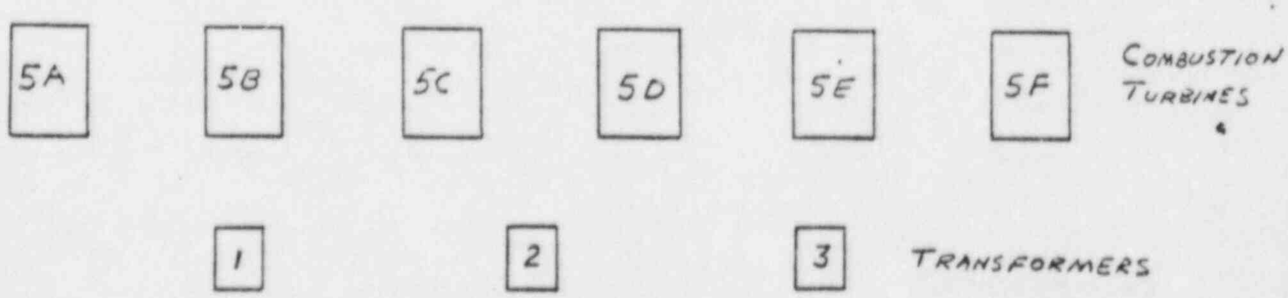
SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION*	CONDITIONS Transformers	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
						SOUND PRESSURE LEVEL, dB RE 20µ N/M² rms — OCTAVE BAND CENTER FREQUENCY, Hz.								
19	20:45	A1	3' W of transformer 3	79	92	53	69	91	82	77	71	68	63	52
20		B1	3' W of transformer 2	80	91	53	66	88	88	78	64	65	61	51
21		C1	3' W of transformer 1	79	89	56	62	84	86	76	71	65	58	49
22		D1	3' S of transformer 1	79	89	64	64	86	82	83	63	49	40	30
23		E1	3' E of transformer 1	78	85	63	64	80	81	82	67	57	44	35
24		F1	3' N of transformer 1	77	90	60	67	89	81	76	61	50	40	33
25		G1	Midway - xformers 1&2	64	80	57	61	81	63	57	49	45	38	28
26		H1	3' N of transformer 2	79	88	62	63	84	83	81	67	51	41	32

DIAGRAM - SHOW MEASURING LOCATIONS:

*See diagram for numbering of transformers



RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 3520[illegible]

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/14/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Transformers
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS: All of the combustion turbines were off

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
21:30	OK					

TEST NO.	TIME	POSITION*	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.								
			Transformers			31.5	63	125	250	500	1000	2000	4000	8000
27	21:15	I1	50' W. of transformer 1	60	71	52	50	64	66	65	53	47	41	33
28		J1	100' W. of transformer 1	55	72	52	53	65	61	54	45	43	36	25
29		K1	At fence, W. of xfmr. 3	54	63	52	48	57	56	55	37	33	30	20
30		L1	At fence, W. of xfmr. 1	56	69	48	53	69	60	55	40	35	27	17
31		M1	At towers, W. of xfmrs.	51	65	50	50	66	49	42	38	35	25	15

DIAGRAM - SHOW MEASURING LOCATIONS:

*See sketch on page 4

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 3520[illegible]

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO.: 042 DATE: 5/15/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

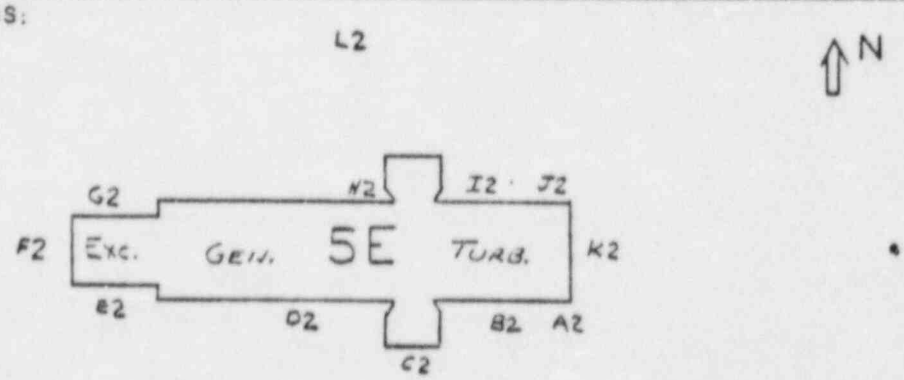
TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
9:00	OK					

PRIMARY NOISE SOURCE: Combustion Turbine
EQUIP. MAKE & MODEL: Westinghouse 60 MW
CLIENT DESIGNATION: 5E
OPERATING CONDITIONS: Unit running at 60 MW

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TEST NO.	TIME	POSITION	CONDITIONS Combustion Turbine 5E	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz: 31.5	63	125	250	500	1000	2000	4000	8000
32	11:05	A2	3' South of turbine	86	103	102	97	94	88	81	76	75	79	69
33		B2	Below intake louvers	83	98	98	90	90	84	80	74	75	68	60
34		C2	3' S. of intake silencer	85	97	95	94	83	83	77	78	81	78	67
35		D2	3' South of generator	90	99	94	90	86	84	81	85	84	81	74
36		E2	3' South of exciter	92	99	91	92	94	86	87	84	85	86	76
37		F2	3' West of exciter	73	96	88	87	81	72	70	66	64	61	51
38		G2	3' North of exciter	90	101	92	98	92	88	87	85	83	81	73
39		H2	3' North of generator	92	102	95	97	85	84	83	83	87	83	75

DIAGRAM - SHOW MEASURING LOCATIONS:



RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC
P.O. Box 2625
BIRMINGHAM, ALABAMA 35[illegible]

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/15/74
OBSERVERS: Hickm an and Champion

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Combustion
EQUIP. MAKE & MODEL: Westinghouse 60 MW
CLIENT DESIGNATION: 5E
OPERATING CONDITIONS: Unit 5E running at 60 MW

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION*	CONDITIONS Combustion Turbine 5E	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz								
40	11:25	I2	3' West of fans	90	104	99	93	88	84	83	84	84	81	74
41		J2	3' North of turbine	90	107	103	99	94	87	82	81	82	85	76
42		K2	3' East of turbine	81	106	102	99	94	85	74	65	64	66	56
43		L2	Midway between 5D & 5E	82	104	101	92	88	81	75	72	74	73	62

DIAGRAM - SHOW MEASURING LOCATIONS:

*See sketch on page 6

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 3520

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/15/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 41-5 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

PRIMARY NOISE SOURCE: Combustion Turbines
EQUIP. MAKE & MODEL: Westinghouse 60 MW
CLIENT DESIGNATION: 5A-5F
OPERATING CONDITIONS: Combustion turbines 5A, 5B, and 5E on

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz								
						31.5	63	125	250	500	1000	2000	4000	8000
44	11:40	M2	100' W. of 5E centerline	72	94	87	86	80	70	71	64	64	60	54
45		N2	200' W. of 5E centerline	66	90	82	81	74	69	63	60	58	54	46
46		O2	300' W. of 5E centerline	64	90	85	82	75	67	62	51	52	48	42
47		P2	400' W. of 5E centerline	60	84	83	30	75	63	55	52	47	45	32
48		Q2	500' W. of 5E centerline	59	82	81	78	72	60	55	46	45	43	31
49		R2	800' W. of 5E centerline	54	78	77	74	66	55	49	39	38	37	22
50		S2	1000' W. of 5E centerline	50	75	75	73	65	54	39	33	32	32	18
51		T2	2000' W. of 5E centerline	40	67	66	62	44	36	35	33	29	25	18

DIAGRAM - SHOW MEASURING LOCATIONS:

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC
P.O. Box 2625
BIRMINGHAM, ALABAMA 3520

CLIENT: Georgia Power Co. - Plant Vogtle
JOB NO: 042 DATE: 5/15/74
OBSERVERS: Hickman and Champion

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Combustion Turbines
EQUIP. MAKE & MODEL: Westinghouse 60 MW
CLIENT DESIGNATION: 5B
OPERATING CONDITIONS: Combustion turbines 5A, 5B, and 5E on

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
12:30	OK					

TEST NO.	TIME	POSITION	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
52	12:10	U2	At turbine - inside encl.	105										
53		V2	Turbine platform	94-96	-									
54		W2	Bearing compartment*	116										
55		X2	Generator intake	114										
56		Y2	Exciter view window	93										
57		Z2	Inside trailer	67										

SOUND PRESSURE LEVEL, dB RE 20μ N/M^2 rms — OCTAVE BAND CENTER FREQUENCY, Hz.

DIAGRAM - SHOW MEASURING LOCATIONS:

*Bearing compartment between turbine and generator

RECOMMENDATIONS:

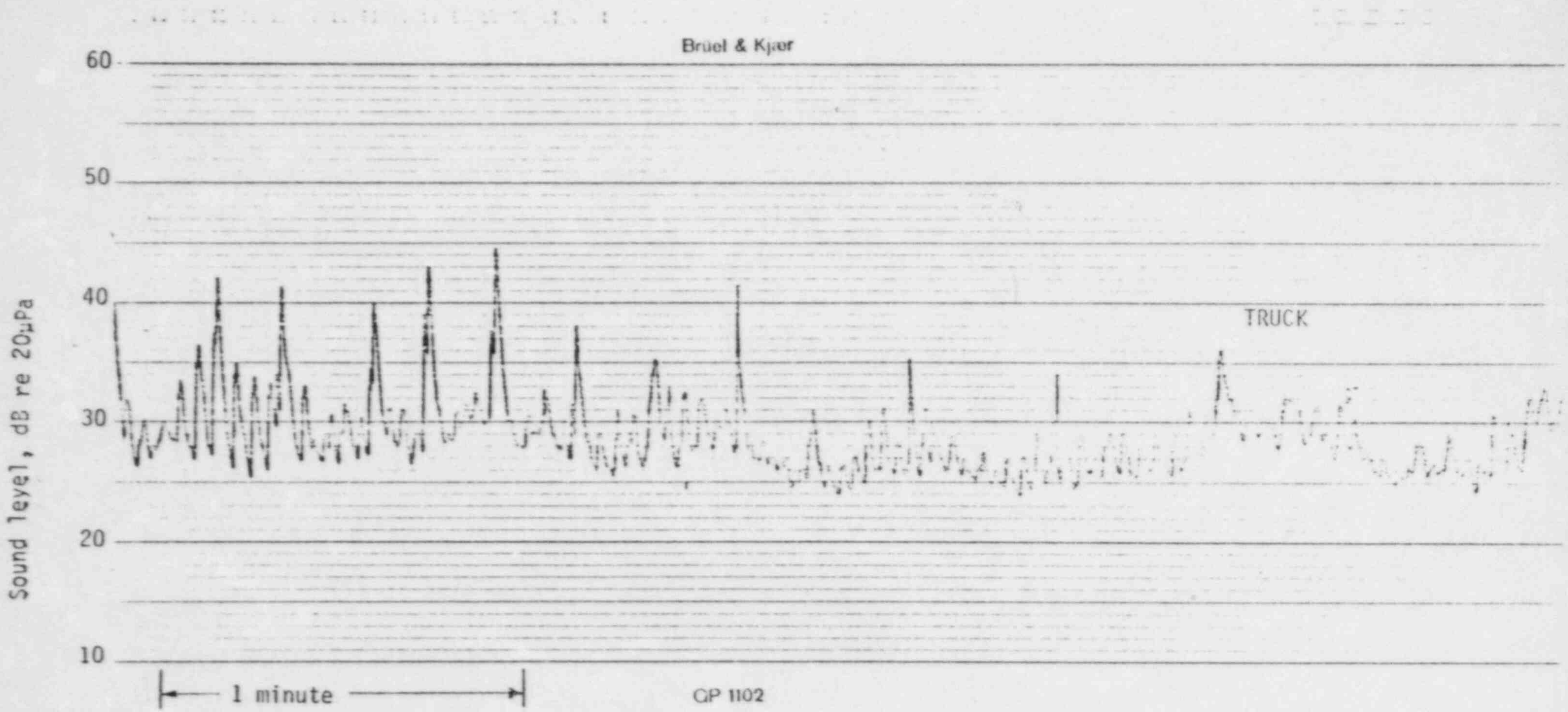


Figure 1. Sound level in dBA measured at plant grid N80+00, E81+00 on May 14, 1974 at 8:25p.m.

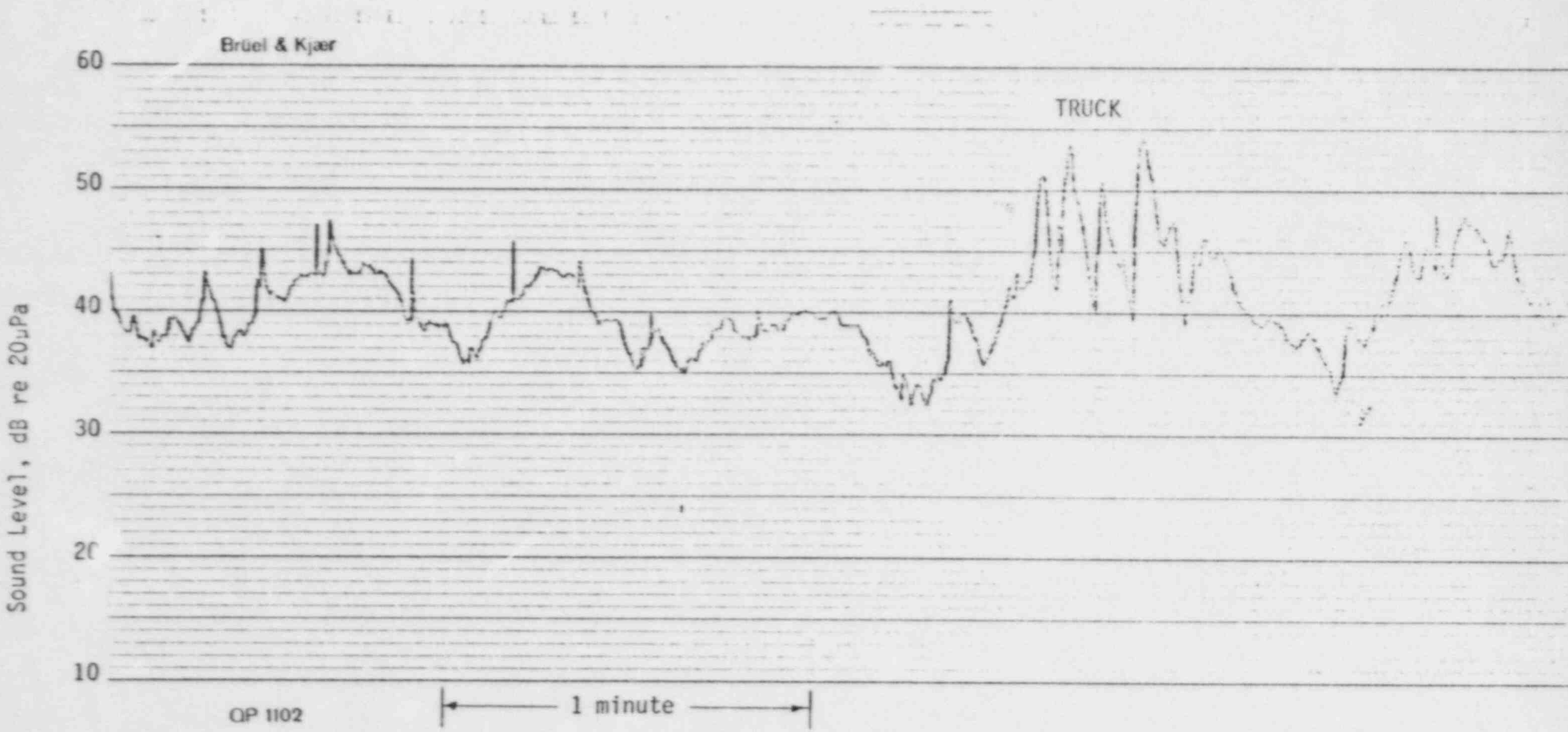
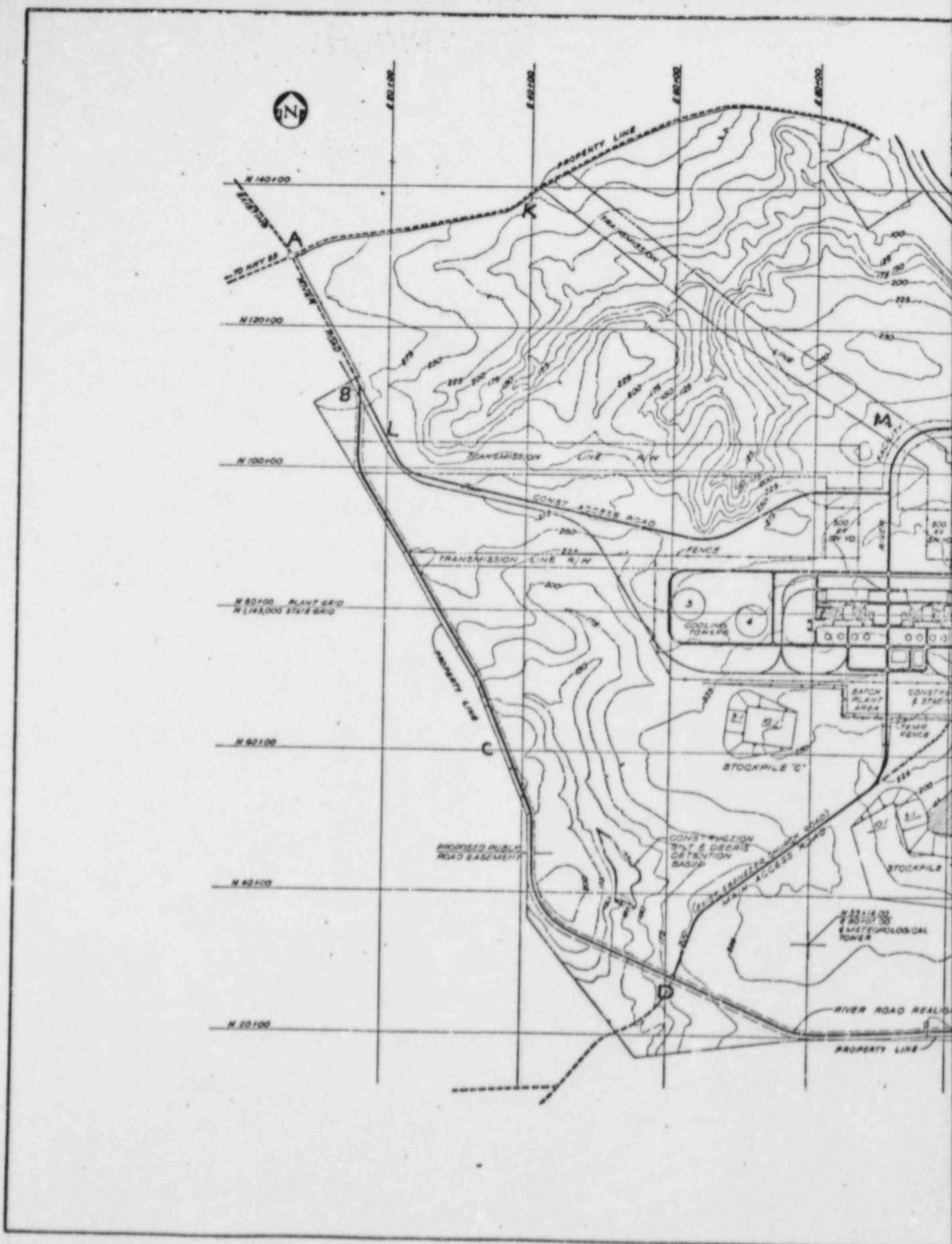
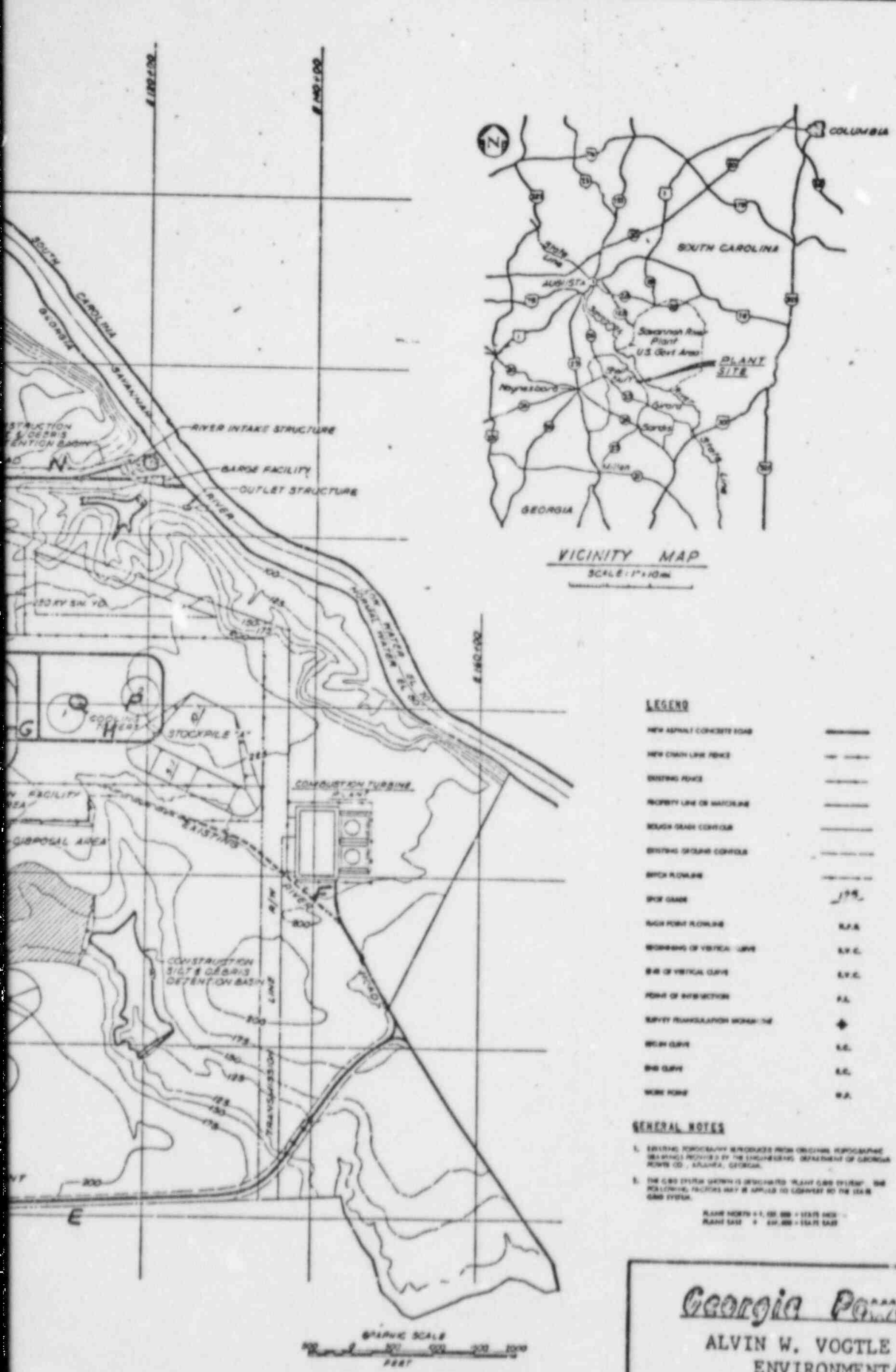


Figure 2. Sound Level in dB linear measured at plant grid N80+00, E81+00 on May 14, 1974 at 8:25 p.m.



N 140+00
N 120+00
N 100+00
N 80+00 PLANT GRID
N 60+00
N 40+00
N 20+00
PROPERTY LINE
TRANSMISSION LINE R/W
CONST ACCESS ROAD
FENCE
COOLING TOWERS
BATCH PLANT AREA
STOCKPILE "C"
STOCKPILE
PROPOSED PUBLIC ROAD EASEMENT
CONSTRUCTION SILT & DEBRIS DETENTION BASIN
MAIN ACCESS ROAD
METEOROLOGICAL TOWER
PROPERTY LINE



Georgia Power Company

ALVIN W. VOGTLE NUCLEAR PLANT
ENVIRONMENTAL REPORT

SITE PLOT PLAN
FIGURE 2.1-3

Amend. 2 11/26/73

CONSTRUCTION SOUND LEVEL SURVEY

Alvin W. Vogtle Nuclear Plant

C. E. Hickman

H. A. Fearing

Southern Company Services, Inc.
Birmingham, Alabama
May 1981

INTRODUCTION

The following sound surveys have been conducted at the Plant Vogtle site as required for plant licensing:

a. A pre-construction survey was performed at the site on May 14-15, 1974.

b. A survey was conducted during plant construction on April 14-17, 1981.

MONITORING LOCATIONS

Pre-Construction Sound Survey (May 14-15, 1974)

Ambient sound levels were measured at nine accessible locations around the property line and at other representative points on the site. Readings were also taken around the combustion turbines already on the site. Sound levels were measured during the morning and evening hours. Results of the survey were transmitted in the 1974 Southern Services, Inc. report, "Sound Level Study at the Alvin W. Vogtle Nuclear Plant Site Prior to Construction."

Construction Sound Survey (April 14-17, 1981)

Readings were taken at eight of the nine 1974 locations along the site property line to facilitate comparison. Sound levels were measured at each of these locations approximately every four hours, from morning until evening. In addition, a continuous sound monitoring system was set up on three consecutive days in three representative locations near the property line. This system made and stored 15-minute averages of sound levels all day and all night in each location. A short tape recording of the sounds was also made at each of these continuous monitoring locations and at a location near the power block.

EQUIPMENT

The equipment used in the surveys is listed below:

May 1974 Survey

Bruel & Kjaer 2209 Sound Level Meter	SN 454249
Bruel & Kjaer 4145 Condenser Microphone	SN 456988
Bruel & Kjaer 1613 Octave Band Analyzer	SN 460875
Bruel & Kjaer 4220 Pistonphone Calibrator	SN 457476
Windscreen	

April 1981 Survey

Bruel & Kjaer 2215 Sound Level Analyzer	SN 691966
Bruel & Kjaer 4165 Condenser Microphone	SN 708658
Bruel & Kjaer 4230 Acoustic Calibrator	SN 725248
Metrosonics dB-602 Sound Level Analyzer	SN 1136
Metrosonics MK-601R 1/4" Microphone	
Metrosonics CL-302 Calibrator	SN 1667
Windscreens	
Nagra DJ Tape Recorder	SN D-4L73

Calibration was performed before and after each set of measurements.

MONITORING PROCEDURE

Pre-Construction Sound Survey

A-weighted sound levels were taken at each location during the survey. In addition, octave band analyses were done at several locations. The measurement locations can be seen in Figure 1.

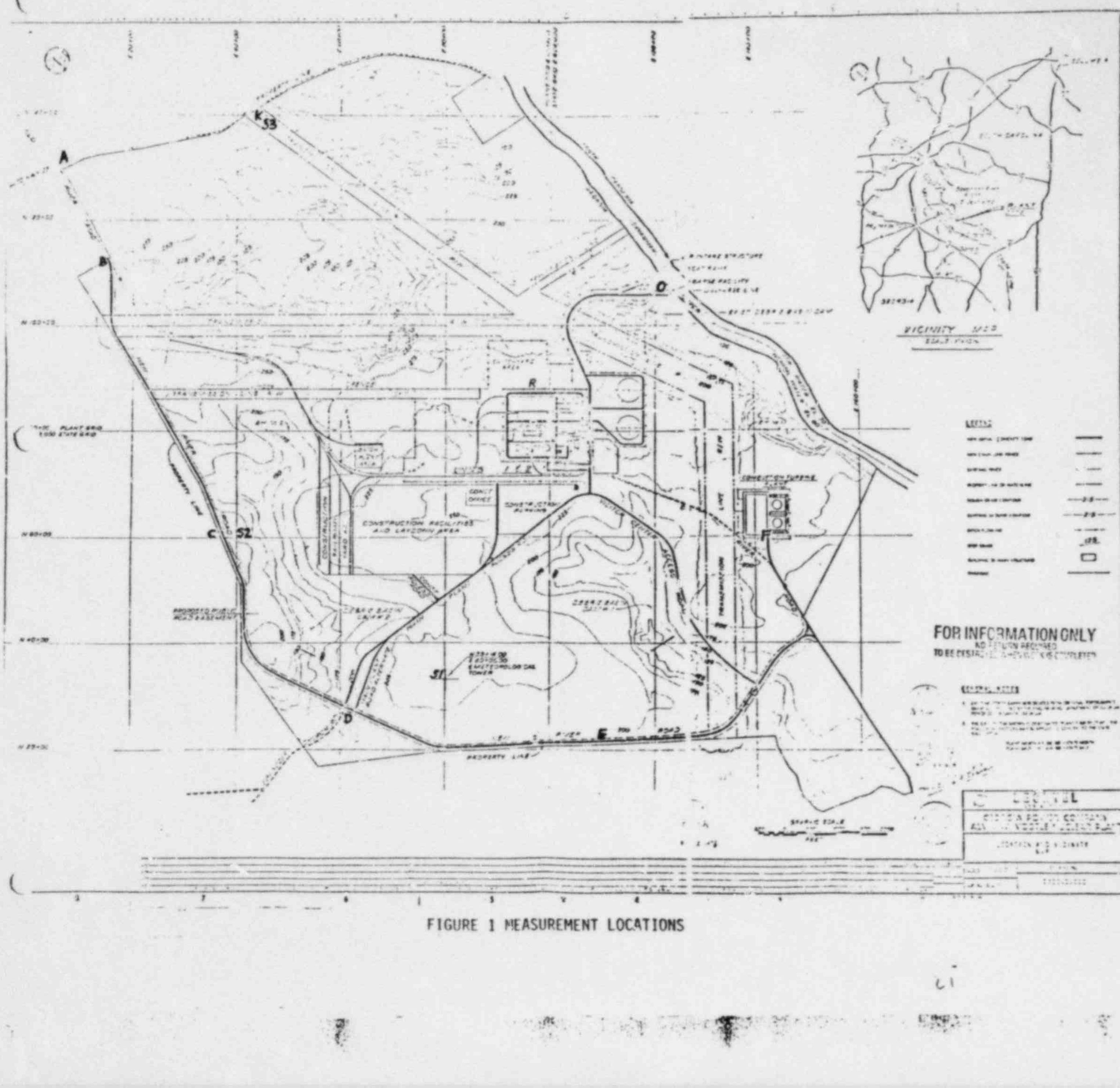


FIGURE 1 MEASUREMENT LOCATIONS

Construction Sound Survey

A-weighted and C-weighted sound levels were measured at each location along the property line. The sound levels were taken when there was little or no road noise or bird noise. In breezy conditions, readings were taken in a calm moment when possible. Timely calibration of the equipment was performed.

INTERPRETATION OF RESULTS

Pre-Construction Survey

Some of the A-weighted sound levels taken in the 1974 survey can be seen in Table 1. Sound levels ranged from 22 to 42 dBA with most readings falling in the 25-30 dBA range. Rustling leaves from wind gusts caused levels of 34 to 44 dBA. Bird calls caused levels of 35-45 dBA. Passing road traffic produced levels of 80-88 dBA at some locations. The combustion turbines were not operating at the time of the property line sound measurements. With the combustion turbines off, transformer noise was dominant at location F.

Construction Sound Survey

Sound level measurements taken along the site property line during the construction survey are compared with pre-construction levels in Table 1. For the construction survey, the range of values measured and the arithmetic average of all readings at each location are tabulated. Increases of 10-15 dB over the 1974 levels seem to have occurred at locations C and D, points relatively close to the main area of construction. Smaller increases were found at locations A, B, E, and K. Location O served as a water pumping station. Levels were generally quiet but

Table 1. Comparison of Pre-Construction Sound Levels with Levels During Construction.

Measurement Location	Pre-Construction Levels (May 1974), dBA	Construction Levels (April 1981), dBA	
		Range	Average
A	27-30	27-40	32
B	25-30	27-39	33
C	25-34	35-47	41
D	22-25	23-47	36
E	25	24-42	31
F	39	46-60	51
K	34	28-35	32
O	40-42	34-55	39

during pumping reached 77 dBA 100 feet from the pump. A complete set of sound level readings is contained on 11 Noise Survey Forms in the Appendix.

Construction noise was barely audible at most measurement locations. The noise typically consisted of steady vehicle and construction sounds, along with occasional loud engine noise from cranes or earth-movers. Other intermittent sounds included beeping from vehicles backing up and pounding from a pile driver. Non-construction sounds present included bird chirping, traffic sounds, and rustling of leaves during breezy conditions. Insect noise was not evident during the daytime measurements. Figures 2, 3 and 4 show how sound levels typically varied with time at monitoring points S1, S2 and S3. Note that the base levels on the charts correspond well with readings taken at these three locations, as recorded in the Noise Survey Forms.

Continuous readings were taken at locations S1, S2 and S3, chosen as representative monitoring points and as relatively safe places to leave the analyzer. Figures 5, 6 and 7 show sound levels energy-averaged at 1-hour intervals at the three locations rounded to the nearest dB. L_{eq} is an energy-average A-weighted sound level. L_{10}, L_{50} and L_{90} are the sound levels exceeded 10, 50 and 90 percent of the time, respectively. L_{10} is also called the "intrusive" noise level. L_{50} is the median sound level. L_{90} can be thought of as the ambient or background noise level and should correspond roughly to the sound level readings taken every four hours along the property line. The complete set of 15-minute average levels can be found in the Appendix.

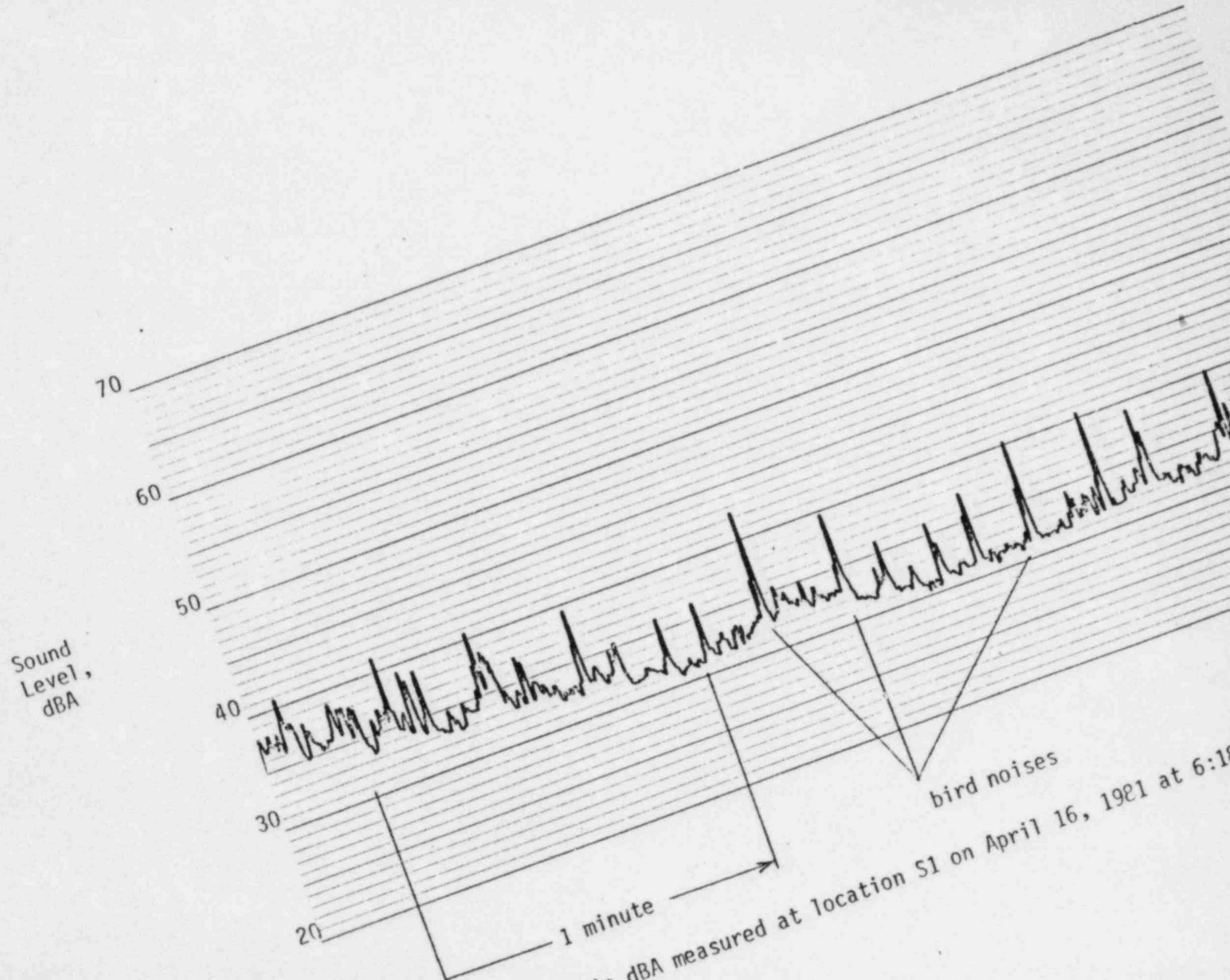


Figure 2. Sound Level in dBA measured at location S1 on April 16, 1981 at 6:18

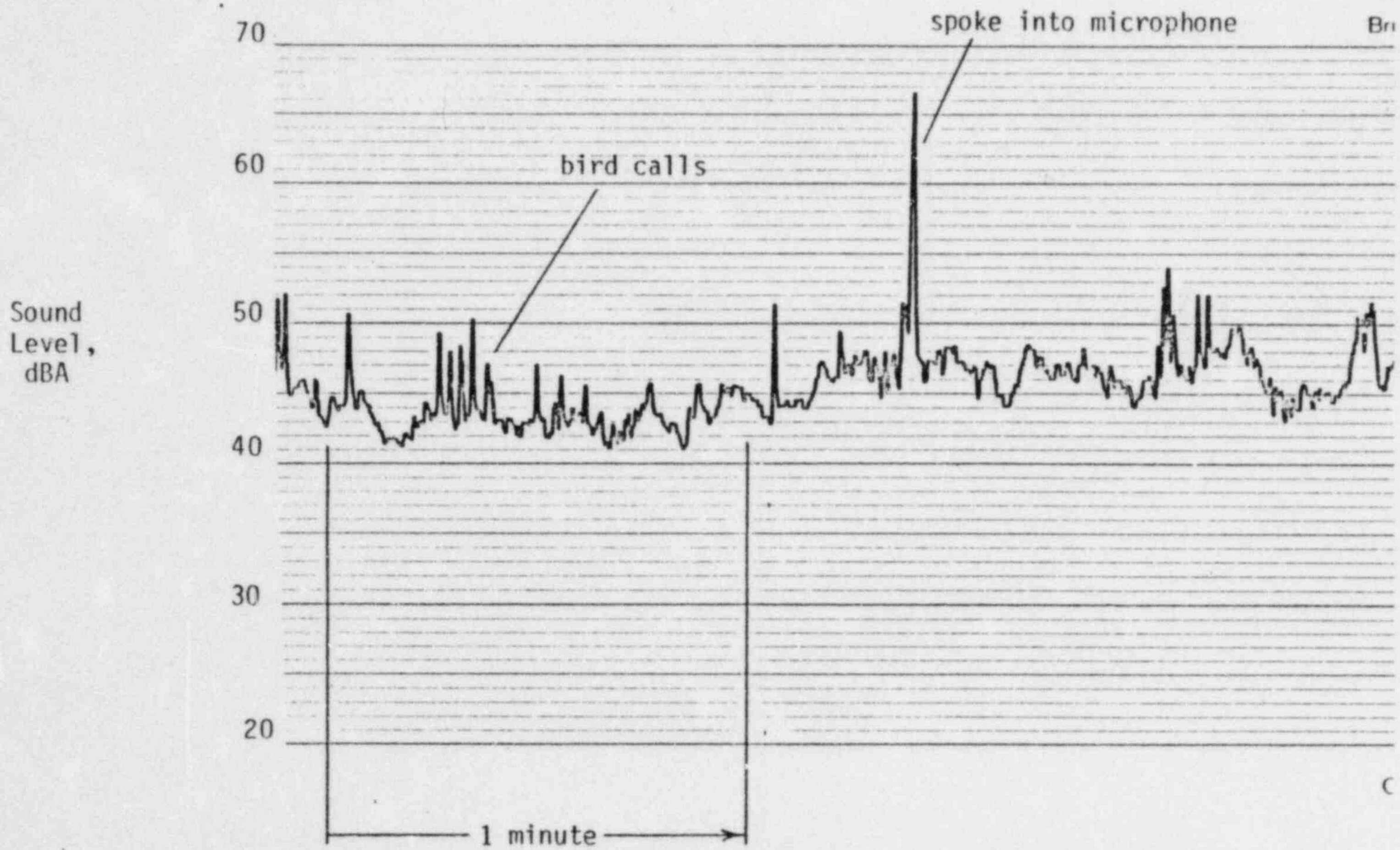


Figure 3. Sound Level in dBA measured at location S2 on April 15, 1981 at 10:35 a.m.

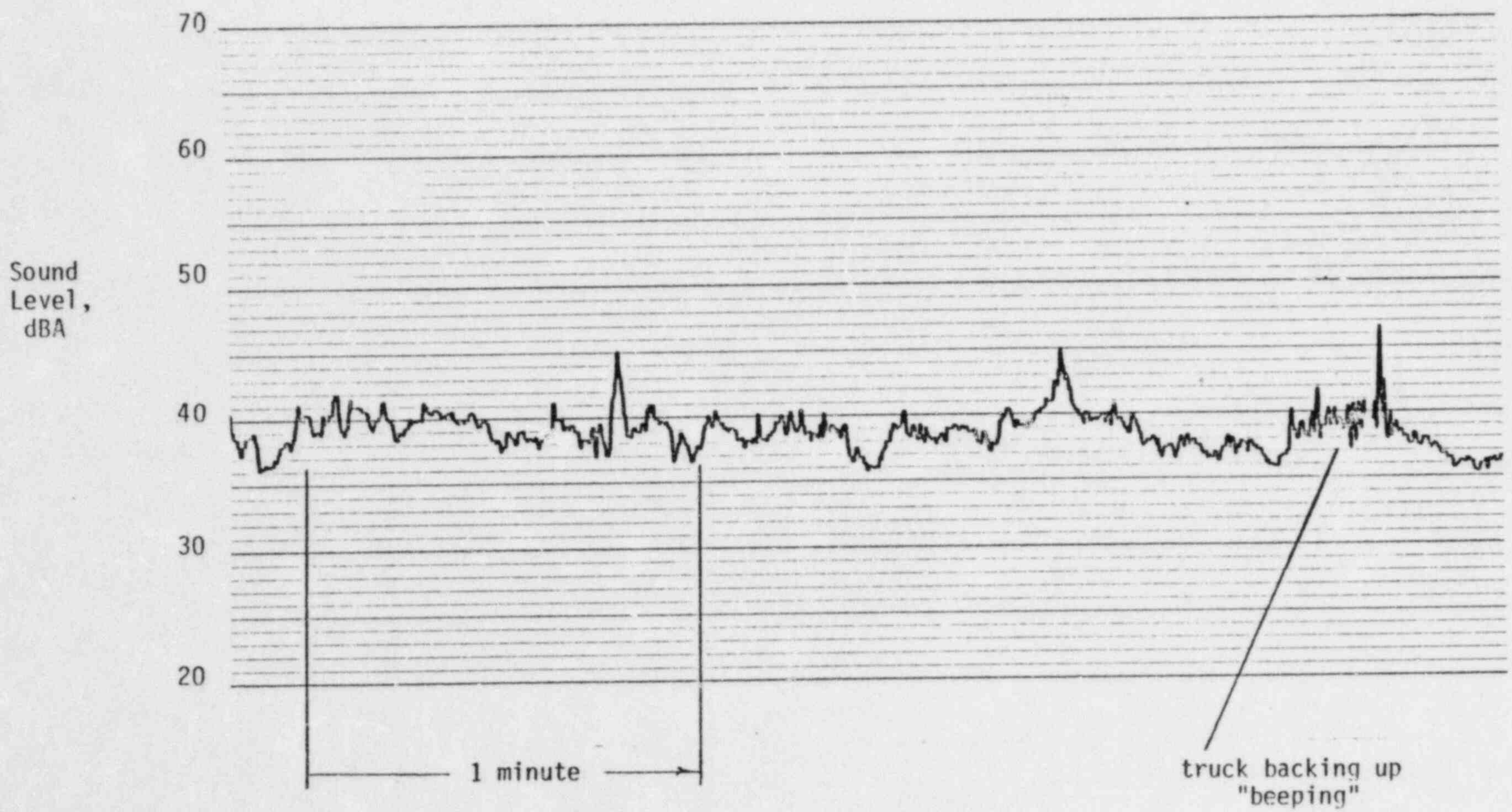


Figure 4. Sound Level in dBA measured at location S3 on April 15, 1981 at 12:54 p.m.

Monitor Site S1 (April 14-15) was located on a bluff overlooking a "spoiling" pit just outside the meteorological station fence. The construction site was partially visible from this location. Notable at S1 (Figure 5) is the sudden increase in levels, especially L_{50} and L_{90}, after 5 p.m. It was learned the day after monitoring that this increase was due to heavy equipment dumping spoiled fill into the pit during the second shift. Weather station records showed winds gusted up to 35 miles per hour in the early morning hours of April 15, which corresponded to higher levels recorded by the monitor. Measurements made during this time were not accurate. Ignoring the data taken during windy conditions, the average L_{eq} for the location was 46 dB.

Figure 6 shows the sound levels recorded at Monitor Site S2 (April 15-16) located about 50 yards north of the new River Road. The construction site was partially visible from this location also. Because of the monitor's proximity to the main road and the restaurant, high sound levels were measured at shift changes from 4-5 p.m. and 12:30-1:30 a.m. and at the supper period from 8-9 p.m. Construction noise, although still low, was more obvious at this location than at any other. This observation is consistent with the L_{10} levels measured; the "background" sound level was considerably higher at location S2 than at the other two monitor sites. Gusty conditions on the morning of April 15 raised measured levels somewhat.

Monitor Site S3 was located about 50 yards from the dirt road northeast of the construction site in the transmission line clearing. Figure 7 shows this site to be the quietest of the three. The average L_{eq} for the monitoring period was 43 dB. A road grader caused high sound levels before 11 a.m. on April 16.

FIGURE 5
PLANT VOGTLE CONSTRUCTION SOUND SURVEY
MONITOR SITE S 1
APRIL 14 - 15, 1981

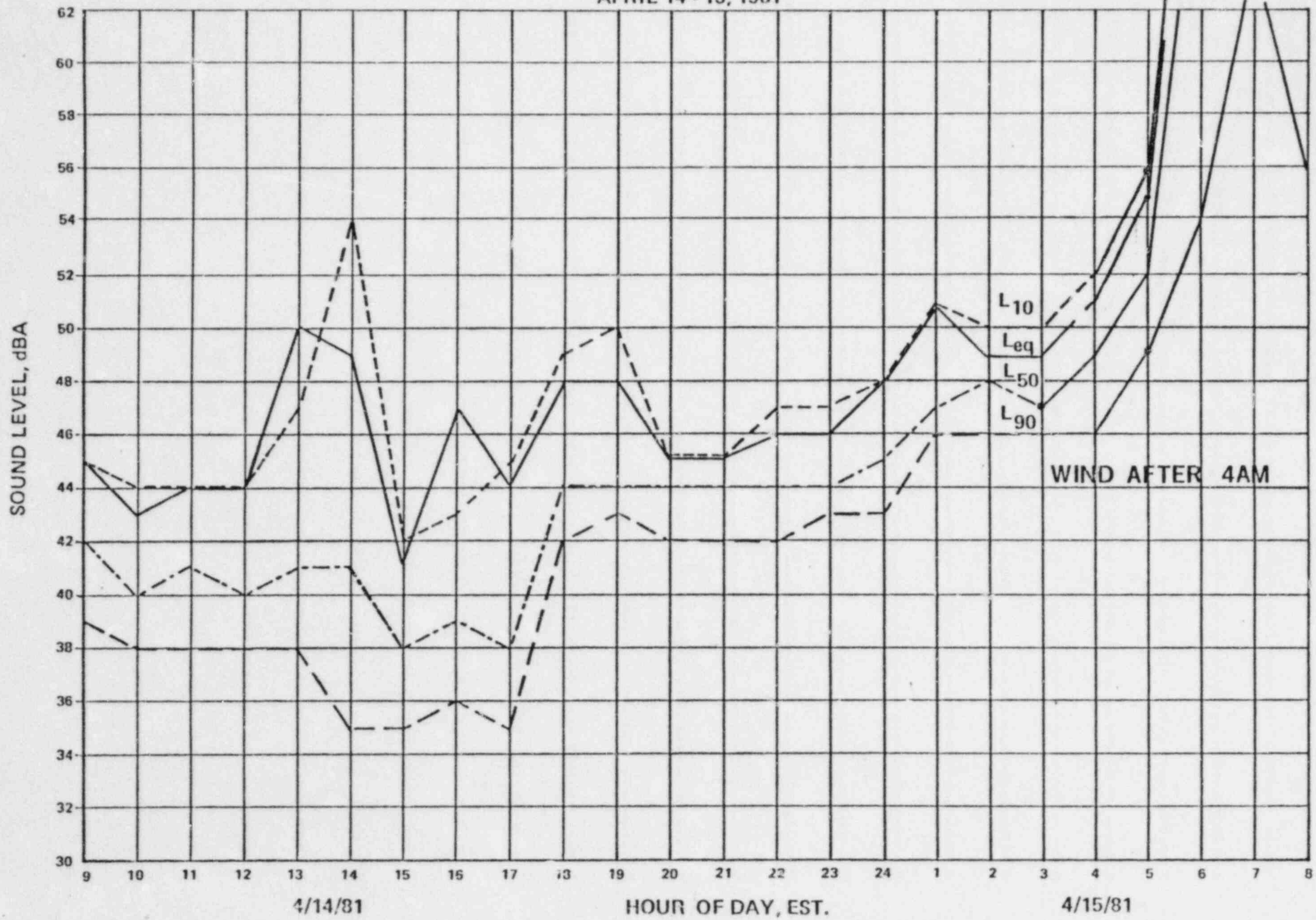


FIGURE 6
PLANT VOGTLE CONSTRUCTION SOUND SURVEY
MONITOR SITE S 2
APRIL 15 - 16, 1981

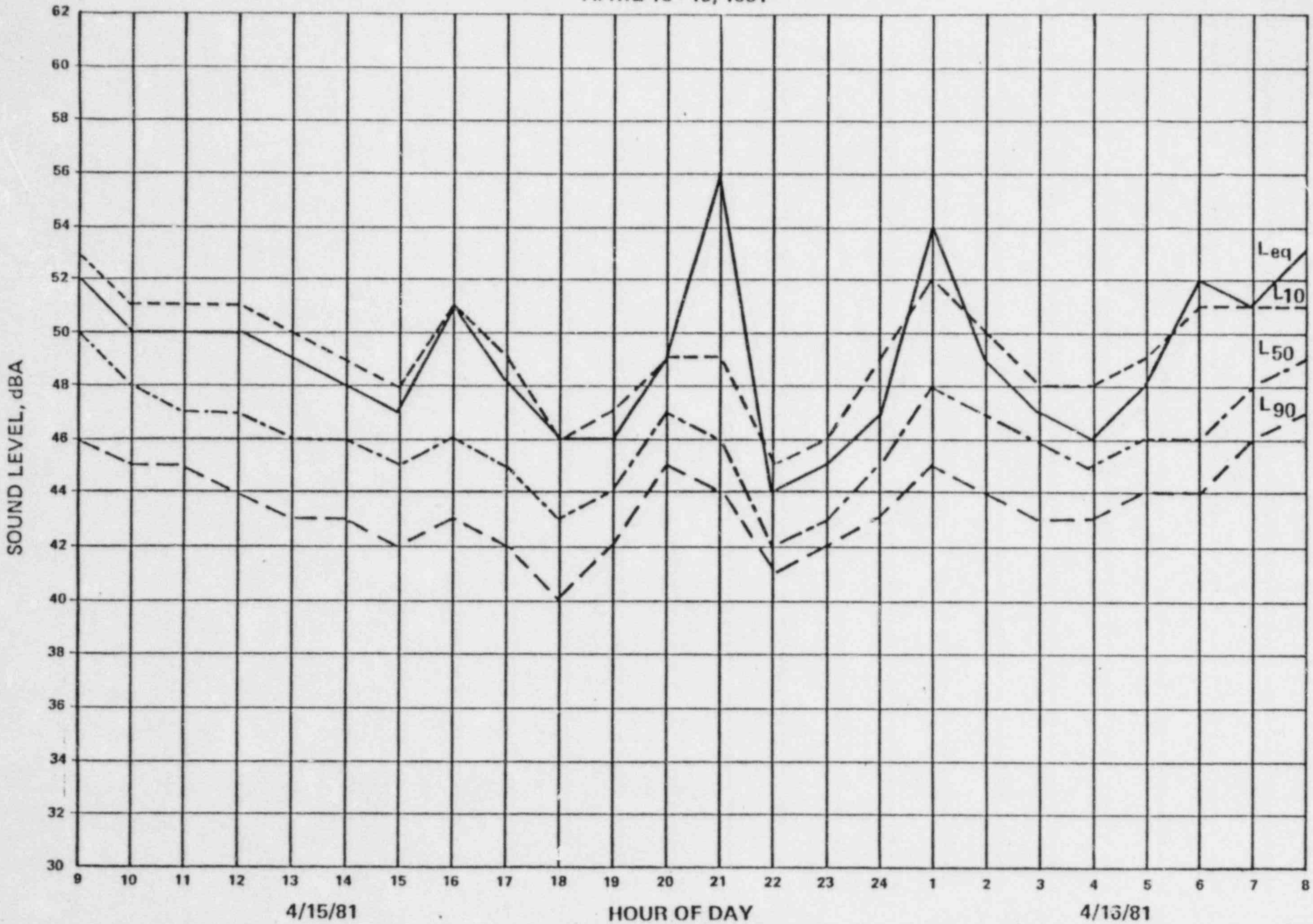
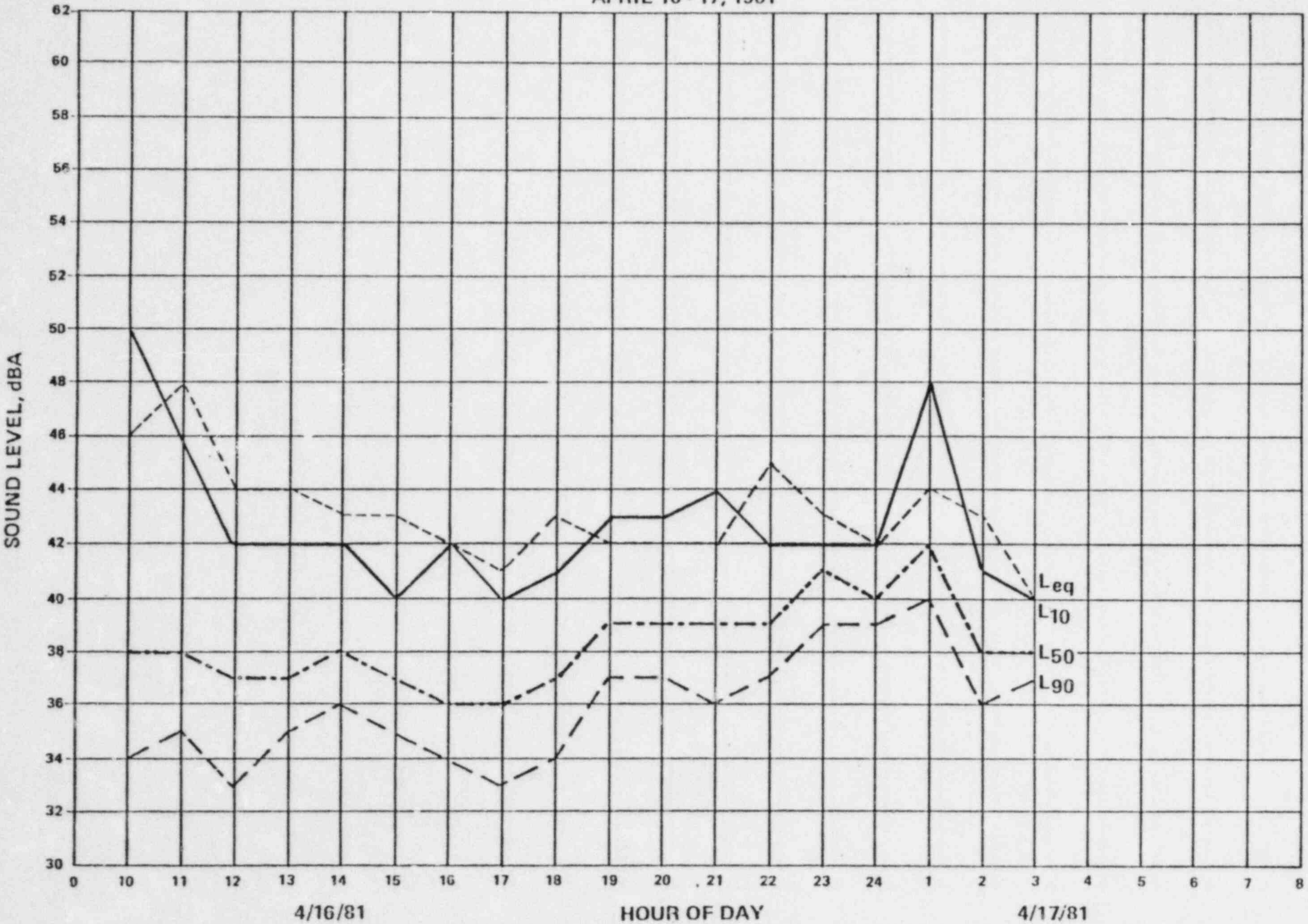


FIGURE 7
PLANT VOGTLE CONSTRUCTION SOUND SURVEY
MONITOR SITE S 3
APRIL 16 - 17, 1981



The Environmental Protection Agency in its March 1974 publication "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," recommends an environmental noise level that does not exceed the day-night average L_{dn} = 55 dB. L_{dn} is defined as:

$$L_{dn} = 10 \log \frac{1}{24} [15 \times 10^{(\frac{L_d}{10})} + 9 \times 10^{(\frac{L_n + 10}{10})}]$$

where L_d is the energy-average A-weighted sound level during the 15 "daytime" hours from 7 a.m. to 10 p.m., the L_n is the average sound level for the nine "nighttime" hours. Using the average L_{eq} values for the daytime and nighttime periods at locations S1, S2 and S3, L_{dn} values were estimated. Table 2 shows the L_{dn} levels are above 55 dB for locations S1 and S2 because of the difficulty in getting only construction noise data during the breezy conditions and shift changes. L_{dn} at location S3 is well below 55 dB with no adjustment.

CONCLUSIONS

Sound levels in some locations along the plant property line have increased since construction has begun. Construction noise at the property line is usually barely audible and is often overshadowed by sounds from traffic, birds, and windy conditions. L_{dn} levels calculated from data taken along the property line do not exceed levels deemed acceptable by the Environmental Protection Agency.

Table 2. Values of L_{dn} Calculated Using L_{eq} Data from Locations S1, S2, and S3.

Monitoring Location	Values (in dBA) calculated using all data.			Values (in dBA) calculated omitting data taken during windy conditions and shift changes.		
	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}
S1	46	51	57	46	49	55
S2	50	50	56	50	48	55
S3	44	44	50			

Appendix

1. Noise Survey Forms
2. 15-minute average levels - Monitor sites S1, S2 and S3.

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant
JOB NO: 042A DATE: 4/14/81
OBSERVERS: Hickman and Fearing

INSTRUMENTATION

SLM: TYPE B&K 2215 SER. # 691966
TRANSDUCER: TYPE B&K 4165 SER. # 708658
ANALYZER: TYPE B&K 2215 SER. # 691966
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4230 SER. # 725248
OTHER: Windscreen

TIME	CALI-BRA-TION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
8:40	94	75				

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TEST NO.	TIME EST	*POSITION	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
1	9:50	A	NW Corner of Property	27	50									
2	10:00	B	N 111 + 00, E 15 + 00	33	49									
3	10:10	C	N 60 + 00, E 37 + 00	41/45	57									
4	10:15	D	At Ebenezer Church Road	33/35	52/55									
5	10:20	E	N 22 + 00, E 110 + 00	30	51									
6	10:25	F	N 60 + 00, E 143 + 00	53	76	76	69	66	53	51	42	42	39	29
7	10:35	V1	Fence-Visitors' Center	55/60	69/73									
8	11:15	O	Intake Structure Area	34/40	53/56									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map

NOTES:

Position A -- Traffic fairly heavy; increased sound levels to 60-74 dBA.
Position B -- Birds increased sound level to 45 dBA; passing traffic produced up to 78 dBA.
Position C -- Construction noise audible.
Position F -- South fence at combustion turbine Plant Wilson; combustion turbine 1C operating (test) at full load.
Position O -- No pumps operating; birds are dominant source.

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant

JOB NO: 042A DATE: 4/14/81

OBSERVERS: Hickman and Fearing

INSTRUMENTATION

SLM: TYPE B&K 2215 SER. # 691966

TRANSDUCER: TYPE B&K 4165 SER. # 708658

ANALYZER: TYPE B&K 2215 SER. # 691966

CABLE: TYPE LENGTH

CALIBRATOR: TYPE B&K 4230 SER. # 725248

OTHER: Windscreen

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
13:43	94					

PRIMARY NOISE SOURCE:

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
9	13:45	A	NW Corner of Property	35/55										
10	13:55	K	N 140 + 00, E 44 + 00	29/33	49/55									
11	14:20	B	N 111 + 00, E 15 + 00	29/35	44/50									
12	14:25	C	N 60 + 00, E 37 + 00	36	50/55									
13	14:27	D	At Ebenezer Church Road	36	53									
14	14:30	E	N 22 + 00, E 110 + 00	27	45/55									
15	14:35	F	N 60 + 00, E 143 + 00	48	63	62	58	62	52	45	37	29	25	--
16	14:55	S1	At Monitor Site 1	33/35	50/55									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Position A -- Traffic noise dominant source.
Position B -- Traffic noise up to 77 dBA measured.
Positions C & D -- Construction noise audible, several birds in area.
Position F -- No combustion turbines operating, substation noise only.
Position S1 -- Monitor Site 1 located near meteorological tower (N 33 + 14.00, E 80 + 05.00).

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant
JOB NO: 042A DATE: 4/14/81
OBSERVERS: Hickman and Fearing

INSTRUMENTATION
SLM: TYPE B&K 2215 SER. # 691966
TRANSDUCER: TYPE B&K 4165 SER. # 708658
ANALYZER: TYPE B&K 2215 SER. # 691966
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4230 SER. # 725248
OTHER: Windscreen

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
						SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms — OCTAVE BAND CENTER FREQUENCY, Hz.								
17	15:20	0	Intake Structure Area	47/55	63									
18	17:22	0	Intake Structure Area	35/40	50/55									
19	17:43	F	N 60 + 00, E 143 + 00	49	65	57	53	64	48	43	37	32	28	--
20	17:53	E	N 22 + 00, E 110 + 00	24	43/47									
21	17:57	D	At Ebenezer Church Road	23	43/45									
22	18:04	C	N 60 + 00, E 37 + 00	30/40	50/60									
23	18:08	B	N 111 + 00, E 15 + 00	27	42/50									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Position 0 -- A crane was operating during Test 17, no nearby work during Test 18.
Position F -- No combustion turbines operating, substation noise only.
Position C -- Considerable activity in DeLaigle Trailer Park.

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant

JOB NO: 042A DATE: 4/14/81

OBSERVERS: Hickman and Fearing

INSTRUMENTATION

SLM: TYPE B&K 2215 SER. # 691966

TRANSDUCER: TYPE B&K 4165 SER. # 708658

ANALYZER: TYPE B&K 2215 SER. # 691966

CABLE: TYPE LENGTH

CALIBRATOR: TYPE B&K 4230 SER. # 725248

OTHER: Windscreen

PRIMARY NOISE SOURCE:

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
18:25	93.3					

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
						SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms — OCTAVE BAND CENTER FREQUENCY, Hz.								
24	18:17	K	N 140 + 00, E 44 + 00	28/35	45									
25	18:21	A	NW Corner of Property	28	46									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Position A -- Traffic still prevalent and often dominant source, aircraft flyover produced 55 dBA.

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant

JOB NO: 042A DATE: 4/15/81

OBSERVERS: Hickman and Fearing

INSTRUMENTATION

SLM: TYPE B&K 2215 SER. # 691966

TRANSDUCER: TYPE B&K 4165 SER. # 708658

ANALYZER: TYPE B&K 2215 SER. # 691966

CABLE: TYPE LENGTH

CALIBRATOR: TYPE B&K 4230 SER. # 725248

OTHER: Windscreen

PRIMARY NOISE SOURCE:

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
8:00	93.8					

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
						SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms — OCTAVE BAND CENTER FREQUENCY, Hz.								
26	10:15	K	N 140 + 00, E 44 + 00	33/34	47									
27	10:22	A	NW Corner of Property	40	50									
28	10:29	B	N 111 + 00, E 15 + 00	37/39	53/55									
29	10:35	C	N 60 + 00, E 37 + 00	45	55									
30	10:45	D	At Ebenezer Church Road	45/47	58/60									
31	10:49	E	N 22 + 00, E 110 + 00	42	55									
32	10:55	F	N 60 + 00, E 143 + 00	60	74									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

All Positions -- High winds precluded sound level measurements between 8:00-10:00 a.m. Wind noise in trees often dominant source from 10:00-11:00 a.m.; 45-50 dBA, 70+ dBC.

Position F -- No combustion turbines operating, compressor running near CT 1F.

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant

JOB NO: 042A DATE: 4/15/81

OBSERVERS: Hickman and Fearing

INSTRUMENTATION

SLM: TYPE B&K 2215 SER. # 691966

TRANSDUCER: TYPE B&K 4165 SER. # 708658

ANALYZER: TYPE B&K 2215 SER. # 691966

CABLE: TYPE ______ LENGTH ______

CALIBRATOR: TYPE B&K 4230 SER. # 725248

OTHER: ______

PRIMARY NOISE SOURCE: ______

EQUIP. MAKE & MODEL: ______

CLIENT DESIGNATION: ______

OPERATING CONDITIONS: ______

SECONDARY NOISE SOURCE: ______

EQUIP. MAKE & MODEL: ______

CLIENT DESIGNATION: ______

OPERATING CONDITIONS: ______

TIME	CALI-BRA-TION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME EST	POSI-TION*	CONDITIONS Construction Noise	SOUND PRESSURE LEVEL, dB RE 20µ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.: 31.5	63	125	250	500	1000	2000	4000	8000
33	13:26	E	N 22 + 00, E 110 + 00	35/38	47/51									
			Intake Structure Area											
34	13:45	0	100' From Pump	77	80	68	67	71	78	72	76	69	65	57
35	14:00	0	280' From Pump-Low Speed	56/63	64/66									
36	14:05	0	280' From Pump-High Speed	65/74	71/74									
37	14:15	0	Pump Off	34	46									
38	14:39	K	N 140 + 00, E 44 + 00	29	45/48									
39	14:43	A	NW Corner of Property	30	46/48									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Position 0 -- A pump used for water supply to sprinkler trucks was operating at the river. The 280' measurements were made to approximate width of river.

All Positions -- Wind speed has diminished considerably.

RECOMMENDATIONS: ______

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant
JOB NO: 042A DATE: 4/15/81
OBSERVERS: Hickman and Fearing

INSTRUMENTATION
SLM: TYPE B&K 2215 SER. # 691966
TRANSDUCER: TYPE B&K 4165 SER. # 708658
ANALYZER: TYPE B&K 2215 SER. # 691966
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4230 SER. # 725248
OTHER: Windscreen

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP	%RH	MMHG	WIND MPH	WIND DIR.
15:36	93.2					

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
40	14:47	B	N 11 + 00, E 15 + 00	33/35	48/50									
41	14:52	C	N 60 + 00, E 37 + 00	44/47	53/56									
42	14:55	S2	At Monitoring Site 2	43/47	54/57									
43	15:10	D	At Ebenezer Church Road	38/41	50/55									
44	15:15	E	N 22 + 00, E 110 + 00	31	45/48									
45	15:20	F	N 60 + 00, E 143 + 00	49	62	57	52	60	50	45	37	33	25	--
46	17:26	O	Intake Structure Area	77	82									

DIAGRAM- SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Position S2 -- Sound levels at Monitoring Site 2 (east of DeLaigle Trailer Park) are essentially identical to those measured at Position C.
Position F -- No combustion turbines operating, substation noise only.
Position O -- A pump used for water supply to sprinkler trucks, was operating at the river measurement taken 100' from the pump.

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant
JOB NO: 042A DATE: 4/15/81
OBSERVERS: Hickman and Fearing

INSTRUMENTATION
SLM: TYPE B&K 2215 SER. # 691966
TRANSDUCER: TYPE B&K 4165 SER. # 708658
ANALYZER: TYPE B&K 2215 SER. # 691966
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4230 SER. # 725248
OTHER: Windscreen

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
19:02	94					

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
47	17:40	F	N 60 + 00, E 143 + 00	49	64	53	50	63	53	44	36	32	22	--
48	17:45	E	N 22 + 00, E 110 + 00	31	43/46									
49	17:50	D	At Ebenezer Church Road	35	50/55									
50	17:55	C	N 60 + 00, E 37 + 00	41/44	51									
51	18:00	S2	At Monitoring Site 2	41/45	50/55									
52	18:10	B	N 111 + 00, E 15 + 00	34	48									
53	18:13	A	NW Corner of Property	32	48									
54	18:17	K	N 140 + 00, E 44 + 00	32/35	48									

DIAGRAM- SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Positions C and S2 -- Sound levels are essentially identical at these two positions.
Positions A and B -- Considerable traffic during measurement time at these two positions.

RECOMMENDATIONS:

NOIS...

...: GPC-Vogtle Nuclear Plant

...: 042A DATE: 4/16/81

...RVERS: Hickman and Fearing

INSTRU...

...LM: TYPE B&K 2215 SER.# 691966

TRANSDUCER: TYPE B&K 4165 SER.# 708658

ANALYZER: TYPE B&K 2215 SER.# 691966

CABLE: TYPE ____ LENGTH ____

CALIBRATOR: TYPE B&K 4230 SER.# 725248

OTHER: Windscreen

PRIMARY NOISE S...

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:

EQUIP. MAKE & MODEL:

CLIENT DESIGNATION:

OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
10:00	94					

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
					SOUND PRESSURE LEVEL, dB RE 20μ N/M^2 rms — OCTAVE BAND CENTER FREQUENCY, Hz.									
55	10:10	K	N 140 + 00, E 44 + 00	31/35	47/50									
56	10:16	A	NW Corner of Property	32	47									
57	10:20	B	N 111 + 00, E 15 + 00	34	48/52									
58	10:30	C	N 60 + 00, E 37 + 00	39/47	50/55									
59	10:35	S2	At Monitoring Site 2	40/47	50/60									
60	10:45	D	At Ebenezer Church Road	37/40	52/55									
61	10:50	E	N 22 + 00, E 110 + 00	34	44/50									
62	10:55	F	N 60 + 00, E 143 + 00	46/49	57	50	46	50	52	50	35	32	30	--

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Position K -- Near Monitoring Site 3; pile driving noise audible, but had insignifican... effect on dBA sound level.

Position S2 -- Magnetic tape recording made at this location; wind gusts produced sound levels of 70 dBC.

Position E -- Very little construction noise audible; several birds in area.

Position F -- No combustion turbines operating; substation noise only.

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant
JOB NO: 042A DATE: 4/16/81
OBSERVERS: Hickman and Fearing

INSTRUMENTATION
SLM: TYPE B&K 2215 SER. # 691966
TRANSDUCER: TYPE B&K 4165 SER. # 708658
ANALYZER: TYPE B&K 2215 SER. # 691966
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4230 SER. # 725248
OTHER: Windscreen

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
17:30	94					

TEST NO.	TIME EST	POSITION *	CONDITIONS Construction Noise	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.: 31.5	63	125	250	500	1000	2000	4000	8000
63	11:25	O	Intake Structure Area	36	50/53									
64	12:55	S3	At Monitoring Site 3	39/45	49/57									
65	17:35	K	N 140 + 00, E 44 + 00	33	47/50									
66	17:39	S3	At Monitoring Site 3	34	48/55									
67	17:47	A	NW Corner of Property	34	46/53									
68	17:50	B	N 111 + 00, E 15 + 00	34	47/50									
69	17:56	C	N 60 + 00, E 37 + 00	35/37	52/55									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located according to "Plant Grid System." See location and vicinity map.

NOTES:

Position O -- Pump not operating, birds increased sound levels to 42 dBA.
Position S3 -- Monitoring Site 3, construction noise audible, magnetic tape recording made at 12:55. (Position S3 near Position K)
Position C -- Construction noise audible, activity in trailer park.

RECOMMENDATIONS:

NOISE SURVEY FORM

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202

CLIENT: GPC-Vogtle Nuclear Plant
JOB NO: 042A DATE: 4/16/81
OBSERVERS: Hickman and Fearing

INSTRUMENTATION
- SLM: TYPE B&K 2215 SER. # 691966
- TRANSDUCER: TYPE B&K 4165 SER. # 708658
- ANALYZER: TYPE B&K 2215 SER. # 691966
- CABLE: TYPE LENGTH
- CALIBRATOR: TYPE B&K 4230 SER. # 725248
- OTHER: Windscreen

PRIMARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
18:20	94					

TEST NO.	TIME EST	POSITION*	CONDITIONS Construction Noise	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
70	17:59	D	At Ebenezer Church Road	32	44/47									
71	18:02	E	N22 + 00, E 110 + 00	27/30	40/45									
72	18:06	F	N 60 + 00, E 143 + 00	48	60	55	50	58	54	46	33	30	26	--
73	18:15	S1	At Monitoring Site 1	30/35	48/52									

DIAGRAM - SHOW MEASURING LOCATIONS:

*Positions are located accoarding to "Plant Grid System." See location and vicinity map.

NOTES:

Position F -- No combustion turbines operating, substation noise only.
Position S1 -- Monitoring Site 1 at meteorological tower; magnetic tape recording made, several birds in area.

RECOMMENDATIONS:

Southern Company Services, Inc.

April 14-15, 1981

DESIGNED ____________ DATE ________

JOB GPC-Vogtle Nuclear Plant

CHECKED ____________ DATE ________

SUBJECT Monitor Site S1 -- Construction Noise

SHEET 1 OF 3

TIME (EST)	L_{eq} dBA		L_{10} dBA		L_{50} dBA		L_{90} dBA		Windspeed MPH
9:00	46		47		43		40		5
	46		44		41		39		
	43		44		41		39		
	42		43		40		38		
10:00	43		45		41		38		5
	43		45		41		39		Gust (10-11)
	42		44		39		37		
	42		43		41		39		
11:00	41		42		39		37		5
	45		45		40		37		
	46		46		43		40		
	45		46		43		41		
12:00	46		44		40		38		5
	40		42		38		35		
	44		41		35		33		
	43		44		41		38		
13:00	41		42		39		37		7
	56		51		42		40		
	42		43		40		38		
	39		41		37		35		
14:00	40		41		38		35		8
	52		56		45		35		Gust (11.5)
	51		57		37		34		
	39		41		35		34		
15:00	39		41		36		34		8
	41		43		38		36		Gust (12-13)
	43		44		41		37		
	41		41		38		35		
16:00	47		40		38		36		5
	46		44		39		37		
	49		44		40		37		
	44		41		38		36		
17:00	40		42		36		34		5
	47		48		40		35		

Southern Company Services, Inc.

April 14-15, 1981

JOB GPC-Vogtle Nuclear Plant

DESIGNED ______ DATE ______
CHECKED ______ DATE ______

SUBJECT Monitor Site S1 -- Construction Noise

SHEET 2 OF 3

TIME (EST)	L_{eq} dBA		L_{10} dBA		L_{50} dBA		L_{90} dBA		Windspeed MPH
	43		46		35		33		
	49		48		36		34		
18:00	48		48		45		43		4½
	49		50		45		43		
	47		49		44		42		
	48		50		44		43		
19:00	49		51		44		43		5
	47		49		44		42		
	47		48		44		43		
	45		44		44		43		
20:00	45		45		44		42		5
	44		44		43		41		(Gust 10)
	45		46		44		43		
	46		46		45		44		
21:00	44		44		42		42		7.5
	44		44		43		41		(Gust 11)
	46		46		44		42		
	44		45		43		42		
22:00	48		47		44		42		7.5
	47		48		44		42		(Gust 13)
	45		46		44		42		
	47		48		44		42		
23:00	44		45		43		42		7.5
	45		46		44		43		(Gust 11.5)
	46		47		45		43		
	48		49		45		44		
24:00	49		50		45		43		5
	47		47		45		43		
	46		47		45		43		
	47		47		45		44		
1:00	54		52		46		45		10
	52		53		50		47		(Gust 17)
	49		50		47		46		
	49		50		48		46		

Form No. 9-337

Southern Company Services, Inc.

April 14-15, 1981

DESIGNED ______ DATE ______

CHECKED ______ DATE ______

JOB GPC-Vogtle Nuclear Plant

SUBJECT Monitor Site S1 -- Construction Noise SHEET 3 OF 3

TIME	L_{eq}		L_{10}		L_{50}		L_{90}		Windspeed
(EST)	dBA		dBA		dBA		dBA		MPH
2:00	50		50		48		47		4
	49		49		47		46		
	49		49		48		46		
	48		49		47		46		
3:00	48		49		47		46		10
	49		49		47		47		(Gust 15)
	49		51		48		46		
	50		51		48		46		
4:00	50		51		48		46		14
	51		52		49		45		(Gust 20)
	52		53		50		45		
	53		54		51		47		
5:00	54		55		52		47		16
	54		55		52		49		Gust (26.5)
	57		58		54		51		
	57		59		54		52		
6:00	74		76		62		51		20
	75		78		68		57		(Gust 34)
	78		81		69		55		
	82		85		76		66		
7:00	81		83		73		62		17.5
	72		75		65		55		(Gust 26)
	70		73		63		52		
	75		78		67		55		
8:00									

Form No. 9-337

Southern Company Services, Inc.

April 15-16, 1981

JOB GPC-Vogtle Nuclear Plant — DESIGNED ____ DATE ____

CHECKED ____ DATE ____

SUBJECT Monitoring Site 2 -- Construction Noise — SHEET 1 OF 3

TIME (EST)	L_{eq} dBA		L_{10} dBA		L_{50} dBA		L_{90} dBA		Windspeed MPH
9:00	52		53		50		47		17.5
	51		52		49		45		(Gust 27)
	50		51		48		44		
	50		51		47		45		
10:00	51		52		48		45		17.5
	50		51		48		46		(Gust 27)
	52		53		49		47		
	50		52		47		45		17.5
11:00	48		49		46		44		Gust (22.5)
	48		50		46		44		
	50		51		47		45		
	51		53		49		46		15
12:00	51		50		45		42		Gust (27.5)
	48		49		46		42		
	50		49		44		40		
	49		51		47		45		
13:00	50		51		47		44		12.5
	47		48		45		42		(Gust 23)
	48		49		46		43		
	47		48		45		43		
14:00	49		50		46		44		10
	48		49		45		43		Gust (19.5)
	47		48		45		42		
	47		48		45		43		
15:00	47		48		45		42		10
	47		48		45		42		(Gust 21)
	47		48		44		42		
	49		50		46		43		
16:00	51		52		46		43		10
	53		52		46		43		(Gust 18)
	50		51		47		45		
	49		51		46		43		
17:00	46		47		43		40		10
	44		46		41		39		(Gust 18.5)

Form No. 9-337

Southern Company Services, Inc.

April 15-16, 1981

JOB GPC-Vogtle Nuclear Plant

DESIGNED ______ DATE ______

CHECKED ______ DATE ______

SUBJECT Monitorinu Site 2 -- Construction Noise

SHEET 2 OF 3

TIME (EST)	L_{eq} dBA		L_{10} dBA		L_{50} dBA		L_{90} dBA		Windspeed MPH
	44		45		42		40		
	46		47		43		40		
18:00	47		46		43		41		7.5
	47		47		42		40		Gust (14.5)
	43		44		41		40		
	45		45		42		40		
19:00	47		49		45		42		6.5
	47		47		45		44		
	48		48		46		44		
	48		48		46		44		
20:00	49		50		47		46		6.5
	49		49		47		46		
	59		48		46		44		
	47		47		45		44		
21:00	58		49		46		44		6
	49		50		47		43		(Gust 11)
	44		45		43		41		
	44		45		43		42		
22:00	43		44		42		40		5
	43		44		41		40		
	44		44		42		40		
	44		44		42		41		
23:00	45		46		44		43		4.5
	46		48		44		42		
	49		50		46		43		
4/16/81	48		50		46		44		
24:00	46		48		44		42		5
	46		47		44		42		
	49		51		46		44		
	57		51		47		45		
1:00	56		53		48		44		5
	51		52		49		45		
	50		49		46		44		
	49		50		47		45		

Form No. 9-337

Southern Company Services, Inc.

April 15-16, 1981

DESIGNED __________ DATE ______

CHECKED __________ DATE ______

JOB GPC-Vogtle Nuclear Plant

SUBJECT Monitor Site 2 -- Construction Noise

SHEET 3 OF 3

TIME (EST)	L_{eq} dBA		L_{10} dBA		L_{50} dBA		L_{90} dBA		Windspeed MPH
2:00	48		49		46		44		6
	49		50		47		44		
	47		48		46		44		
	47		48		46		44		
3:00	48		49		46		43		7.5
	46		47		45		42		
	47		48		46		44		
	48		49		46		44		
4:00	46		48		44		41		7.5
	43		44		42		40		
	44		46		43		41		
	49		50		47		44		
5:00	49		50		47		44		6
	49		50		47		45		
	57		55		48		45		
	47		48		46		44		
6:00	48		48		46		43		6
	47		48		45		44		
	49		50		47		44		
	53		53		49		46		
7:00	51		51		48		46		7.5
	49		50		48		46		(Gust 15)
	50		50		48		47		
	55		52		49		46		

Southern Company Services, Inc.

April 16-17, 1981

JOB GPC-Vogtle Nuclear Plant

DESIGNED ________ DATE ________

CHECKED ________ DATE ________

SUBJECT Monitor Site 3 -- Construction Noise

SHEET 1 OF 3

TIME (EST)	L_{eq} dBA	L_{10} dBA	L_{50} dBA	L_{90} dBA
10:15	39	41	36	33
	53	48	39	35
	46	48	37	35
11:00	49	50	40	35
	40	41	37	35
	45	48	37	34
	40	42	37	34
12:00	44	45	37	33
	41	44	35	32
	43	46	38	33
	44	45	37	33
13:00	41	44	37	35
	43	46	38	35
	40	41	37	35
	42	43	38	35
14:00	41	42	38	35
	41	43	38	36
	43	45	38	36
	39	40	37	35
15:00	43	46	38	35
	40	42	36	34
	38	39	36	35
	40	40	36	35
16:00	43	41	36	34
	43	44	38	35
	42	43	35	33
	37	39	35	33
17:00	42	44	37	33
	40	42	35	33
	37	38	35	33
	40	41	35	33
18:00	43	46	38	34
	42	44	37	34
	38	39	36	34

Form No. 9-337

Southern Company Services, Inc.

April 16-17, 1981

JOB GPC-Vogtle Nuclear Plant

DESIGNED ____ DATE ____

CHECKED ____ DATE ____

SUBJECT Monitor Site 3 -- Construction Noise

SHEET 2 OF 3

TIME (EST)		L_{eq} dBA		L_{10} dBA		L_{50} dBA		L_{90} dBA	
		40		41		38		35	
19:00		42		42		39		37	
		46		43		39		37	
		41		42		39		37	
		42		42		40		39	
20:00		42		42		40		38	
		41		42		39		37	
		46		40		36		34	
		38		39		36		34	
21:00		49		44		38		35	
		41		42		40		37	
		41		42		40		37	
		46		50		40		37	
22:00		40		41		38		36	
		40		40		38		37	
		40		41		39		36	
		41		42		40		38	
23:00		42		43		41		39	
		43		43		41		39	
		43		44		42		40	
4/17/81		42		43		41		39	
24:00		42		43		41		39	
		41		42		40		38	
		41		41		39		38	
		50		43		40		39	
1:00		50		44		42		40	
		43		44		41		39	
		45		45		43		41	
		42		44		40		37	
2:00		43		45		38		37	
		41		41		37		35	
		39		40		37		36	
		39		39		37		36	
3:00		41		41		39		38	

Form No. 9-337

Southern Company Services, Inc.

April 16-17, 1981

JOB GPC-Vogtle Nuclear Plant

DESIGNED ____ DATE ____

CHECKED ____ DATE ____

SUBJECT Monitor Site 3 -- Construction Noise

SHEET 3 OF 3

TIME (EST)		L_{eq} dBA		L_{10} dBA		L_{50} dBA		L_{90} dBA	
3:15		40		40		39		37	

Form No. 9-337

C.E. Hickman

VEGP-OLSER-Q

Question E290.16:

Provide report on noise from natural and mechanical draft cooling towers entitled "Cooling Tower Noise" prepared by Southern Company Services. Noise data on the circular mechanical-draft cooling towers are presented there.

Response:

A ~~One~~ copy of ~~the~~ this report ~~requested is enclosed~~. was provided by D.O. Foster's letter to H.R. Denton dated May 15, 1984.

TABLE OF CONTENTS

COOLING TOWER NOISE

INTRODUCTION

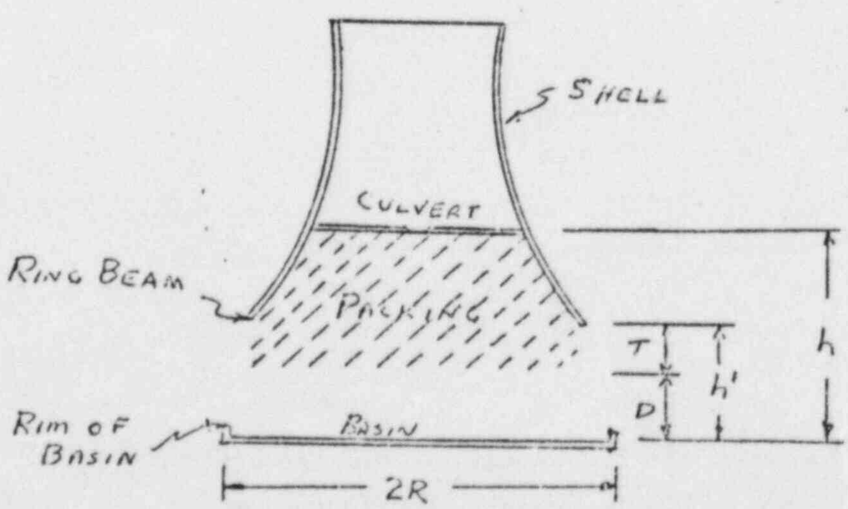
A number of investigations have been conducted on the noise generated by and radiated from cooling towers. Both natural draft and mechanical draft towers have been considered. Some of the theories and results are presented below.

SOUND LEVEL PREDICTION METHODS AND MEASUREMENTS

Some of the sound level prediction techniques are more sophisticated mathematically than others in that formulas are derived based on the configuration of the tower, whereas other prediction techniques depend upon empirical relationships developed from measured data. Brief summaries of attached documents follow.

A. R. M. Ellis Prediction Method for Natural Draft Towers

One of the first sound level prediction techniques was reported by R. M. Ellis in the Journal of Sound and Vibration (1971), Vol. 14(2), pp. 171-182. A sketch showing the dimensions required in the derived formulas is shown below.



Applicable formulas are

(a) A-weighted Acoustic Power

$$W_{ac} = Mh \left[0.95 \times 10^{-5} \left(\frac{T}{h} \right)^2 + 1.8 \times 10^{-5} \left(\frac{D}{h} \right)^2 \right] \qquad (1)$$

(b) A-weighted Sound Level at the Rim of the Basin

$$p_{rim}^2 = \frac{W_{ac} \times Z_o}{2\pi R h'} \qquad (2a)$$

$$L_{p_{rim}} = 20 \log_{10} \frac{p_{rim}}{p_{ref}} \; ; \; p_{ref} = 20 \mu\text{Pascal} \qquad (2b)$$

(c) A-weighted Sound Level at a Distance "a" From the Rim

$$p_a^2 = \frac{W_{ac} \times Z_o}{\pi^2 (a^2 + 2aR)} \tan^{-1} \sqrt{\frac{a+2R}{a}} \qquad (3a)$$

$$L_{p_a} = 20 \log_{10} \frac{p_a}{p_{ref}} \qquad (3b)$$

(d) Distances Greater Than 30 meters

For distances greater than 30 meters the sound level octave band spectrum at the rim should be used and the octave band levels should be further corrected for atmospheric absorption using the following data.

Table I

Center Frequency (Hz)	500	1000	2000	4000	8000
Atmospheric Absorption (dB/300m)	0.7	1.4	3.0	7.7	14.4

The symbols used in the above equations are defined as

M = mass flow rate of cooling water (kg/sec)

h = distance the water falls from the culvert into the basin (meters)

h' = depth of the open area below the tower shell; from basin to ring beam (meters)

T = depth of packing below ring beam (meters)

D = height from basin to base of packing (meters)

R = radius of tower (meters)

Z_0 = characteristic impedance of air = $\rho_0 C$ = 407 mks rayls at 22°C and barometric pressure of 0.751 mHg.

B. J. P. Carlson and A. M. Teplitzky - Consolidated Edison Company of New York

The paper "Environmental Noise Impact of Natural Draft Hyperbolic Cooling Towers" was presented at the Acoustical Society of America meeting on April 24, 1974. Based upon noise measurements and effects of water loading on noise emissions, the A-weighted sound level at 40 feet from the rim of the water basin is estimated by the following two equations:

$$L_{40} = 71 + 10 \log \left(\frac{M}{A} \right) \text{dBA} \qquad (4)$$

for crossflow towers and

$$L_{40} = 75.5 + 10 \log \left(\frac{M}{A} \right) \text{dBA} \qquad (5)$$

for counterflow towers where

L_{40} = A-weighted sound level at 40 feet

M = water flow rate in gallons per minute

A = active area of the tower in ft^2

The active area of a cooling tower is considered the area of the water basin for counterflow towers and the mean area of the fill for crossflow towers.

The 40 foot distance was selected since it is in the near field of the tower and the sound level measured would not be altered significantly by structural elements of the tower. Divergence of sound to the far field can be calculated using the equations developed by Ellis as described above.

C. G. Capano and W. E. Bradley - Stone and Webster

The paper "Acoustical Impact of Cooling Towers" was also presented at the ASA meeting in New York on April 24, 1974. Acoustical data shown represent actual field measurements of sound levels in dBA versus distance for eight wet natural draft cooling towers with water capacities ranging from 140,000 to 500,000 GPM.

D. J. E. Shahan - Sargent and Lundy

Data presented in the report "Noise Control of Power Plant Cooling Towers. A Study of the Size of Buffer Zone Required to Meet Various Noise Criteria" are based on the following assumptions:

1. The noise levels in dBA for natural draft towers vary directly with $\left[10 \log_{10} (GPM)\right]$ and with $\left[10 \log_{10} (HP)\right]$ for mechanical draft towers where GPM = water flow to the tower and HP = total cooling tower fan horsepower.

2. The measured data was extrapolated beyond 2000-3000 feet omitting additional acoustic energy loss due to atmospheric absorption, as a conservative estimate.

Several graphs illustrate the range of tower noise levels for plants of various megawatt capacities. Additional graphs show the distances from cooling towers at which various dBA noise level limits will be obtained. The "specific noise control area" which is the total area of land required for noise control is defined in ft^2/megawatt for both mechanical draft and natural draft towers.

E. Draft Document for Edison Electric Institute

A draft of a document "Cooling Tower Noise Emissions" for use by the Edison Electric Institute contains data based primarily on measurements made by R. T. Laudenat of Northeast Utilities. The results indicate significantly higher noise levels from mechanical draft towers as compared to natural draft towers at distances greater than 2000' from the towers.

F. Ecodyne Mechanical Draft Towers

The Ecodyne Corporation has developed for mechanical draft towers a graph of overall sound power level (L_w) versus total rated horsepower (HP) of tower fans. A set of curves providing total attenuations to be subtracted from the sound power level to obtain the sound pressure level at various distances from the source is also provided.

G. Southern Services, Inc. Sound Level Measurements

A number of sound level measurements have been made around both natural draft and mechanical draft towers in The Southern Company system. Noise

Survey Forms illustrate the actual sound level measurements and list some of the characteristics of the towers.

CALCULATIONS OF NOISE ASSOCIATED WITH COOLING TOWERS

Consider a counterflow natural draft tower with the following characteristics

$M = 258,400$ gpm $= 16,300$ kg/sec

$R = 138' = 42$ m

$T = -2' = -0.61$ m ; Assume $T = 0$ for analysis

$D = h' = 30' = 9.15$ m

$h = 37' = 11.3$ m

$A = \pi R^2 = 59,828$ ft^2

A. Use Ellis Prediction Method

1. A-weighted acoustic power

$$W_{ac} = Mh\left[0.95\times10^{-5}\left(\frac{T}{h}\right)^2 + 1.8\times10^{-5}\left(\frac{D}{h}\right)^2\right]$$

$$= (16.3\times10^3)(11.3)\left[0.95\times10^{-5}\left(\frac{0}{11.3}\right)^2 + 1.8\times10^{-5}\left(\frac{9.15}{11.3}\right)^2\right]$$

$$= 2.17$$

2. A-weighted sound level at the rim of the basin

$$p_{rim}^2 = \frac{W_{ac}\times Z_o}{2\pi R h'}$$

$$p_{rim}^2 = \frac{(2.17)(407)}{2\pi(42)(9.15)} = 0.366$$

$$p_{rim} = 0.605$$

$$L_{p_{rim}} = 20 \log \frac{0.605}{20 \times 10^{-6}} =$$

$$L_{p_{rim}} = 89.6 \text{ dBA}$$

3. A-weighted sound level at 40' = 12.19 m.

$$p_a^2 = \frac{W_{ac} \times Z_o}{\pi^2 (a^2 + 2aR)} \tan^{-1} \sqrt{\frac{a + 2R}{a}}$$

$$= \frac{(2.17)(407)}{\pi^2 [(12.19)^2 + 2(12.19)(42)]} \tan^{-1} \sqrt{\frac{12.19 + 2(42)}{12.19}}$$

$$p_a^2 = 0.094$$

$$p_a = 0.306$$

$$L_{p_a} = 20 \log \frac{0.306}{20 \times 10^{-6}}$$

$$L_{p_a} = 83.7 \text{ dBA at 40 feet}$$

B. Carlson - Teplitzky ; Con. Ed Method

$$L_{40} = 75.5 + 10 \log \left(\frac{M}{A} \right) \quad dBA$$

counterflow towers

$$= 75.5 + 10 \log \left(\frac{258,400}{59,828} \right)$$

$$L_{40} = 81.9 \quad dBA$$

C. Summary for 258,400 GPM Counterflow Tower

Distance, Feet	Ellis Pred.	Con. Ed.* Meas.	Con. Ed.* Pred	Bradley Meas.	Southern Services Tower 1 Meas.	Southern Services Tower 2 Meas
At rim	89.6	—	—	84	85	84
40'	83.7	80	80.5[a]	78	78	76
80'	79.8	77	75.5	74	74	73

* Results reported for 250,000 GPM tower in their report

a. L_{40} = 81.9 dBA for tower specified.

D. Consider counterflow tower with one-half of water supply bypassed

$M_{rated} = 310,000$ GPM

$M_{act.} = 155,000$ GPM $= 9770$ kg/sec

$R = 158.5' = 48.4$ m ; $A = \pi R^2 = 78,924$ ft^2

$T = 0$

$D = h' = 34' = 10.4$ m

$h = 44' = 13.4$ m

<u>Ellis Method</u>

$$W_{ac} = (9770)(13.4)\left[1.8 \times 10^{-5}\left(\frac{10.4}{13.4}\right)^2\right]$$

$$W_{ac} = 1.42$$

$$p_{rim}^2 = \frac{(1.42)(407)}{2\pi(48.4)(10.4)} = 0.183$$

$$p_{rim} = 0.427$$

$$L_{p_{rim}} = 20 \log_{10} \frac{0.427}{20 \times 10^{-6}}$$

$$L_{p_{rim}} = 86.6 \text{ dBA}$$

Sound level at $40' = 12.19$ m

$$p_a^2 = \frac{(1.42)(407)}{\pi^2\left[(12.19)^2 + 2(12.19)(48.4)\right]} \tan^{-1}\sqrt{\frac{12.19 + 2(48.4)}{12.19}}$$

$$p_a^2 = 0.055$$

$$p_a = 0.235$$

$$L_{p_a} = 20 \log_{10} \frac{0.235}{20 \times 10^{-6}} = 81.4 \text{ dBA at } 40'$$

Consolidated Edison Method

$$L_{40} = 75.5 + 10 \log_{10} \frac{155,000}{78,924}$$

$$\underline{L_{40} = 78.4 \text{ dBA}}$$

Summary

Distance, Feet	Ellis Pred.	Con. Ed. Pred.	SSI Meas.
At rim	86.6	—	82
40'	81.4	78.4	75

OCTAVE BAND ANALYSIS

A. Natural Draft Towers

Measurements taken around natural draft cooling towers indicate a broadband sound level spectrum with no discrete tones. Some observers have reported hearing discrete tones but these results are not documented.

Plots of the octave band sound level data for three natural draft towers measured by Southern Services personnel are shown on Figure 1 for positions at the rim of the basin and at 100' from the rim.

B. Mechanical Draft Towers

Similarly the sound level spectrums for mechanical draft towers are broadband with no discrete tones. The spectrums at the base of the tower near the louvers and at 100' and 200' perpendicular to the louver side are plotted on Figure 2.

On the same figure appear spectrums near the base of the end wall and at a distance of 50' from the end wall.

Note the distinct directional characteristics of the tower; 84 dBA near the base along louver wall and 68 dBA near the base at the end wall.

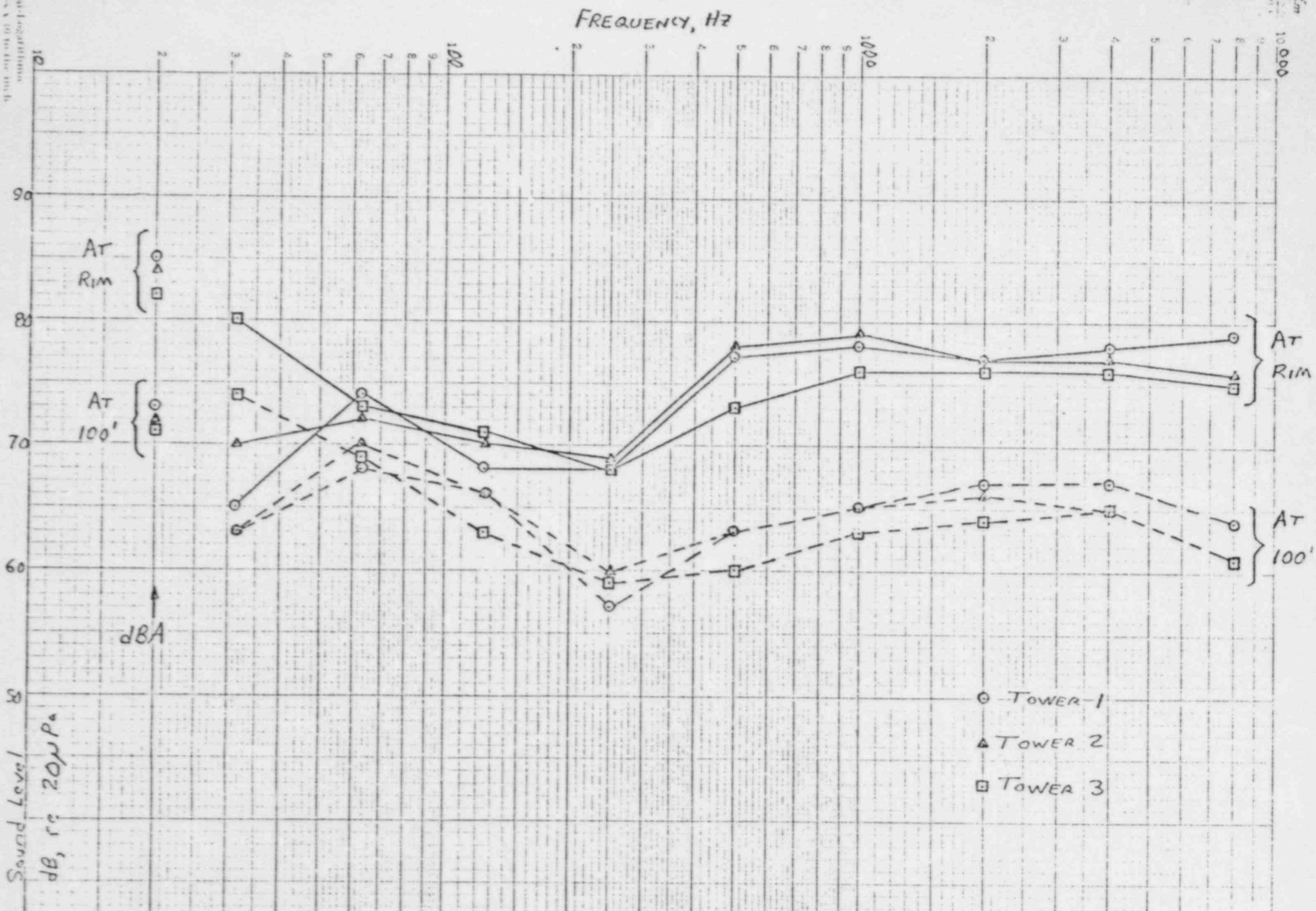


Figure 1. Sound Levels Around Natural Draft Cooling Towers

Semi-Logarithmic
3 Cycles x 10 to the inch

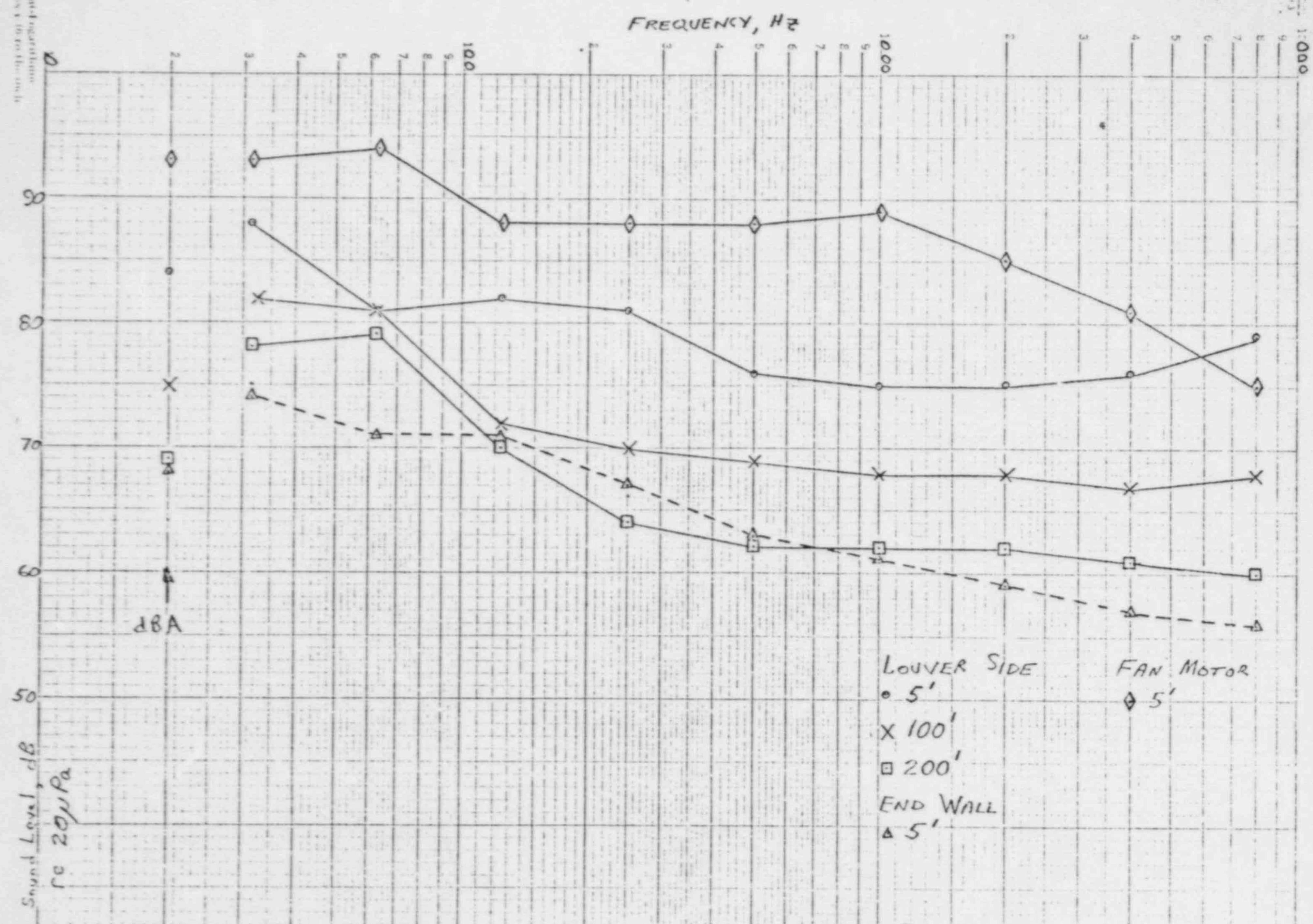


FIGURE 2. SOUND LEVEL AROUND MECHANICAL DRAFT COOLING TOWER

ECODYNE - MECHANICAL DRAFT

1. Tower Data

   Motor size = 150 HP

   Number of cells per tower = 14

   ∴ Total HP = 150 × 14 = 2100

2. Find sound power level, L_w, from the horsepower vs L_w curve

   L_W = PWL = 138 dB re 10^{-13} watt

3. Find the sound attenuations for 100 feet and subtract in each octave band from L_W

Octave Band Center Frequency, Hz

	63	125	250	500	1000	2000	4000	8000
L_W	138	138	138	138	138	138	138	138
Atten, at 100'	55	58	61	64	65	68	70	70
L_p @ 100'	83	80	77	74	73	70	68	68

84.8   78.6   74.8   71

85.8   76.3

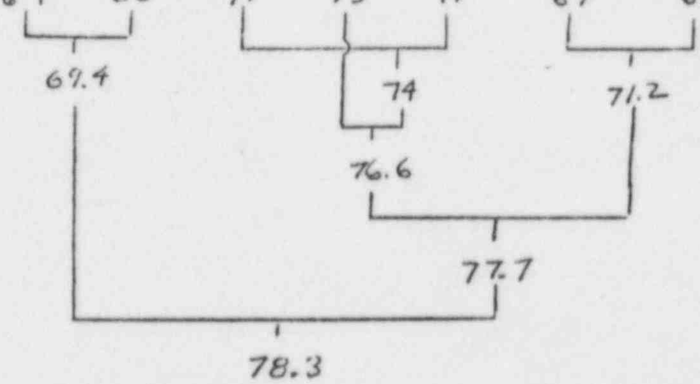
86.3

∴ Overall L_p ≃ 86 dB

4. Calculate dBA at 100 feet

Octave Band Center Frequency, Hz

	63	125	250	500	1000	2000	4000	8000
L_p @ 100'	83	80	77	74	73	70	68	68
A-wty.	-26	-16	-9	-3	0	+1	+1	-1
	57	64	68	71	73	71	69	67



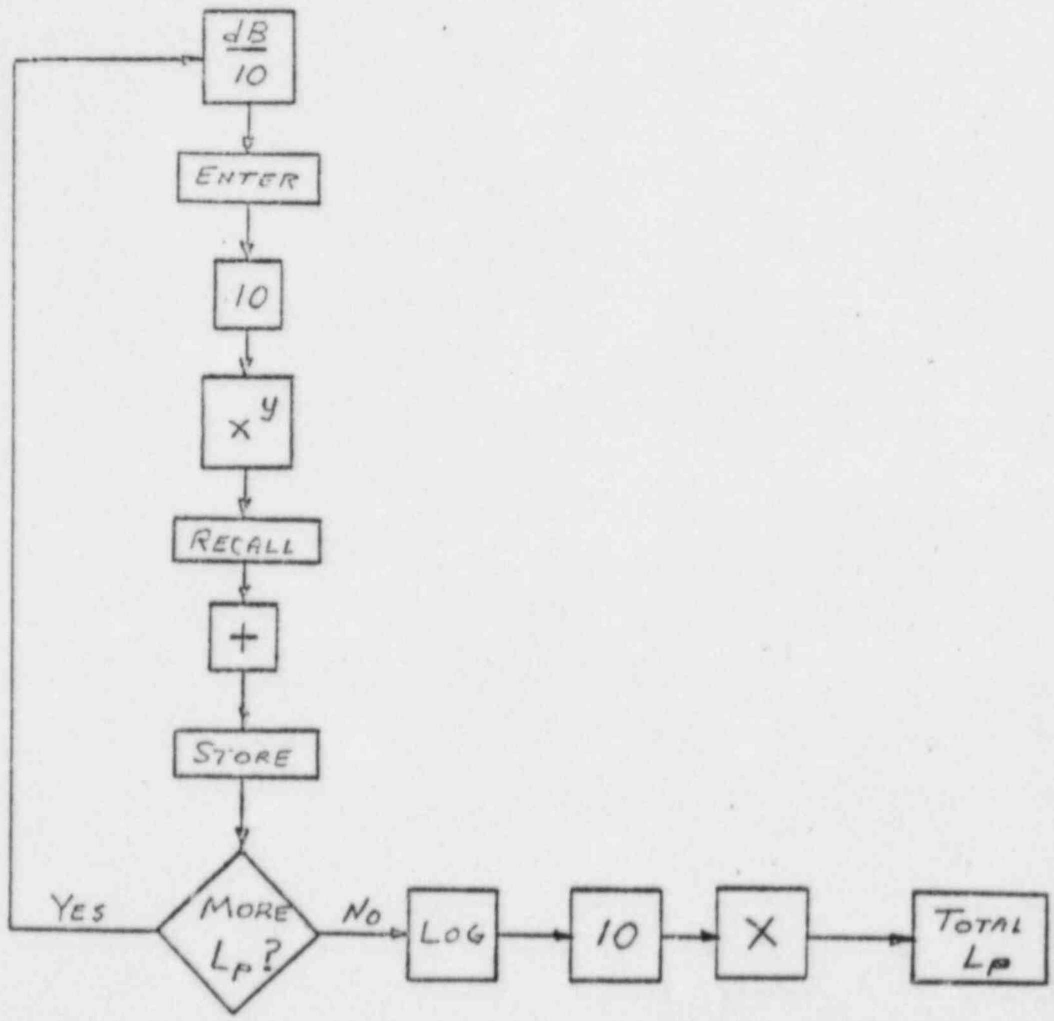
$L_p \simeq 78$ dBA at 100'

NOTES

1. These values fall within envelop shown by Bradley for mechanical draft towers

2. $L_p = 75$ dBA at 100' was measured for a tower with 8 cells.

SUMMATION OF SOUND LEVELS USING HP-35



$$dB_n = 10 \log \left(\frac{P_n}{P_{ref}} \right)^2$$

$$\left(\frac{P_n}{P_{ref}} \right)^2 = 10^{\frac{dB_n}{10}}$$

$$L_{P_T} = 10 \log \left(\frac{P_T}{P_{ref}} \right)^2$$

$$= 10 \log \left[\left(\frac{P_1}{P_{ref}} \right)^2 + \left(\frac{P_2}{P_{ref}} \right)^2 + \cdots + \left(\frac{P_n}{P_{ref}} \right)^2 \right]$$

DESCRIPTIVE DATA AND ENGINEERING INFORMATION

The following descriptive data and engineering information are furnished in connection with this proposal.

1. Design Water Flow - GPM (XXXX tower) Inlet to-	258,400
2. Temperature of Water to Tower - °F	120.6
3. Temperature of Water from Tower - °F	95
4. Wet Bulb Temperature - °F	76
5. Dry Bulb Temperature - °F	88
6. Relative Humidity - %	58
7. Range - °F	25.6
8. Approach - °F	19
9. Pumping Head Above Sill Level - Ft.	* 42'-8"
0. Mean Fill Cross Sectional Area - $Ft.^2$	53,000
1. Fill Wetted Surface - $Ft.^2$	9,500,000
2. Effective Splash Surface - $Ft.^2$	------
3. Effective Cooling Volume - $Ft.^3$	1,960,000
4. Tower Loading - $GPM/Ft.^2$	4.86
5. Dry Air Quantity - lbs./hr.	
(a) At 76°F Wet Bulb and 59% R.H.	65×10^6
(b) At 25°F Wet Bulb and 75% R.H.	100×10^6
6. Draft - inches H_2O	
(a) At 76°F Wet Bulb and 59% R.H.	0.32
(b) At 25°F Wet Bulb and 75% R.H.	0.58
7. Resistance of Air Inlet - Vel. Heads	0.5
8. Resistance of Fill - Vel. Heads	17
9. Air Inlet Area - $Ft.^2$	20,000
0. Temperature of Air/Vapor Mix at Exit at 76°F Wet Bulb and 59% R.H. °F	111

* Note - This is the total head required to elevate and distribute the hot water.

1. Stack exhaust velocity - fps	13.6
2. Drift Loss - Max. %	0.2
3. Diameter of Tower at Sill Level - Ft.	276'
4. Diameter of Tower at Top of Air Inlet - Ft.	259
5. Diameter of Tower at Throat - Ft.	155
6. Diameter of Tower at Exit - Ft.	169
7. Height of Tower above Sill - Ft.	389
8. Height of Throat above Sill - Ft.	311
9. Height of Air Inlet above Sill - Ft.	30
0. Height of Top of Fill above sill - Ft.	37
1. Depth of Basin below Sill - Ft.	6
2. Normal Water Level below Sill - Ft.	0.5
3. Height of Sill above Grade - Ft.	2
4. Thickness of Shell - In. (Minimum)	6
5. Thickness of Ring Girder - In.	48 (avg.)
6. Diameter of Supporting Columns - In.	25"
7. Concrete Mix and Compression Strength Used in Design - psi	
(a) Shell	4,000
(b) Ring Cirder and Columns	4,000 and 5,000
(c) Basin	4,000
(d) Internal Structure	5,000
8. Weights	
(a) Internals - Dry - Tons	7,300
Operating - Tons	9,000
(b) Shell Structure - Tons	16,000
(c) Water in Basin - Tons	10,000

78'
155' Dia
359'
130' Dia
311'
10'
6'
N. 8'6"
276' DIA
4'3"
2. 38 diagonals
Reinforced con

J. Sound Vib. (1971) **14** (2), 171–182

COOLING TOWER NOISE GENERATION AND RADIATION

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An investigation has been carried out into the generation of noise by large natural-draught cooling towers, and the mechanism of noise radiation from them, based on measurements made at four large power stations.

An expression relating the A-weighted acoustic power of a tower to its physical characteristics has been derived. This, together with the discovery that the towers behave as area sources at low frequencies and as arc sources at high frequencies, has enabled a complete prediction method to be proposed. This method was used to estimate the noise from three further cooling towers and gave excellent agreement with the levels which were subsequently measured.

1. INTRODUCTION

The noise levels around power stations are, in many cases, dominated by the noise from the cooling towers, which is almost white in character. The noise is caused by the cooling water falling into the pond which covers the whole area of the base, and also by the water falling onto the packing of the tower, which in some cases protrudes below the shell of the tower. typical tower is shown diagrammatically in Figure 1.

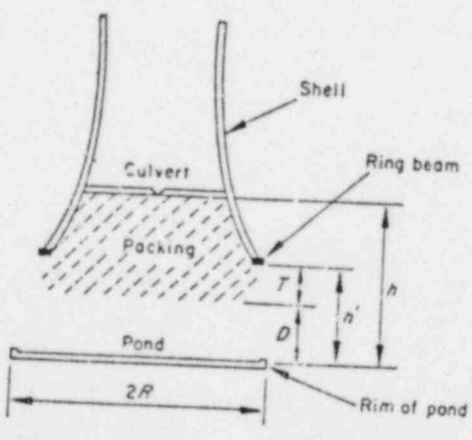

Figure 1. Typical cooling tower construction.

The satisfactory prediction of noise levels due to cooling towers will depend not only on the acoustic power generated by the towers, but also on the mechanism of the propagation of this noise away from the towers. Two possible theoretical approaches to the radiation have been investigated, and compared with measurements made at four large power stations.

An attempt has been made to relate the A-weighted acoustic power output of the four towers to their physical characteristics, so that a complete prediction method could be devised. This method was used to predict the cooling tower noise at three further power stations, and the resulting levels were then compared with the measured levels.

2. THEORETICAL SOUND RADIATION

The first approach is to consider that the noise is generated by a ring of falling water, around the edge of the pond, and that any noise generated inside this ring is prevented from escaping by reflection, refraction and absorption by the packing and falling water. The total sound pressure at any point will thus be due to the portion of the ring which would be visible to an observer at that point (Figure 2). This approach is considered relevant to the high-frequency noise and, because of the predominance of the high frequencies in the spectrum, to the A-weighted sound level.

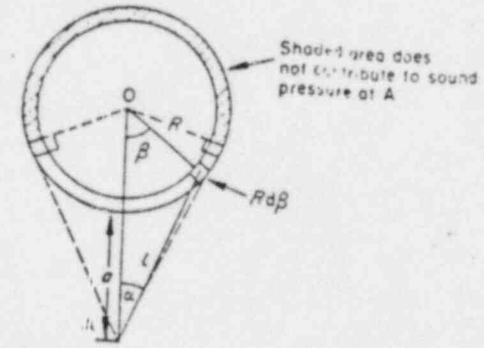

Figure 2. Sound radiation from a ring source.

The sound pressure at A due to an element of length $R\mathrm{d}\beta$, assuming uniform hemispherical radiation, will be given by

$$(P_{r.m.s.})^2_{R\mathrm{d}\beta} = \frac{W_{ac}}{2\pi R}\cdot\frac{Z_0}{2\pi l^2}\cdot R\,\mathrm{d}\beta,$$

where W_{ac} is the acoustic power of the whole ring, Z_0 is the characteristic impedance of air, R is the radius of the rim of the pond and l is the distance from the element to point A.

The total sound pressure at A due to the visible section of the ring will be given by

$$(P_{r.m.s.})^2 = \frac{W_{ac}Z_0}{4\pi^2}\int_{\alpha+\beta=-\pi/2}^{\alpha+\beta=\pi/2}\frac{\mathrm{d}\beta}{l^2},$$

which yields the equation

$$(P_{r.m.s.})^2 = \frac{W_{ac}Z_0}{\pi^2}\cdot\frac{1}{(a^2+2aR)}\cdot\tan^{-1}\sqrt{\left[\frac{a+2R}{a}\right]}. \qquad (1)$$

where a is the distance from the rim to point A.

Where

$$a \ll R, \qquad \tan^{-1}\sqrt{\left[\frac{a+2R}{a}\right]} \to \frac{\pi}{2}, \qquad \frac{1}{a^2+2aR} \to \frac{1}{2aR},$$

so

$$(P_{r.m.s.})^2 = \frac{W_{ac}Z_0}{4\pi aR}, \qquad (2)$$

i.e. a fall in sound pressure level of 3 dB for every doubling of a.

Where

$$a \gg R, \qquad \tan^{-1}\sqrt{\left[\frac{a+2R}{a}\right]} \to \frac{\pi}{4}, \qquad \frac{1}{a^2+2aR} \to \frac{1}{a^2}.$$

$$(P_{r.m.s.})^2 = \frac{W_{ac} Z_0}{4\pi a^2}, \tag{3}$$

a fall in sound pressure level of 6 dB for every doubling of a.

Equations (2) and (3) intersect where $a = R$, whereas equation (1) is a smooth curve having the same initial and final slopes and values as (2) and (3), as shown in Figure 3.

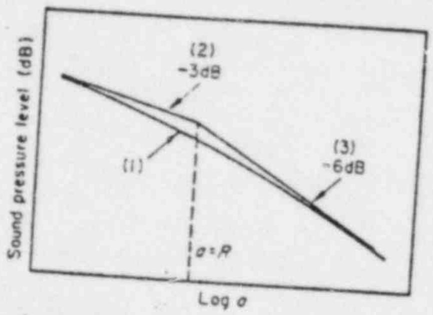

Figure 3. Sound pressure level attenuation with distance, from the ring source shown in Figure 2.

The second approach is to consider that noise is generated across the whole surface of the pond, and radiated hemispherically. This approach was considered relevant to the noise in the low-frequency bands, and possibly to the overall sound pressure level. Examination of Figure 4 shows that the acoustic power due to an element of area $r\,d\beta\,dr$ will be

$$(W_{ac}/\pi R^2)\, r\, d\beta\, dr,$$

and the total pressure at A will be given by

$$(P_{r.m.s.})^2 = \int_0^{2\pi}\int_0^{R} \frac{W_{ac}}{\pi R^2}\cdot\frac{Z_0}{2\pi l^2}\cdot r\, d\beta\, dr.$$

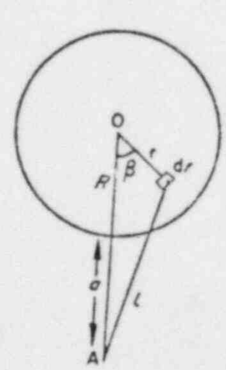

Figure 4. Sound radiation from an area source.

This yields the equation

$$(P_{r.m.s.})^2 = \frac{W_{ac} Z_0}{2\pi R^2} \log_e\left[\frac{(R+a)^2}{(R+a)^2 - R^2}\right], \tag{4}$$

which can be expanded in the form

$$(P_{r.m.s.})^2 = \frac{W_{ac} Z_0}{2\pi R^2}\left[\frac{R^2}{(R+a)^2} + \frac{1}{2}\left\{\frac{R^2}{(R+a)^2}\right\}^2 + \frac{1}{3}\left\{\frac{R^2}{(R+a)^2}\right\}^3 + \cdots\right].$$

When $a \ll R, P$ varies slowly with a, and when $a \gg R, P \propto 1/a$, i.e. a 6 dB fall per doublin of a.

The variation of sound pressure level with distance from the tower will be as shown i Figure 5.

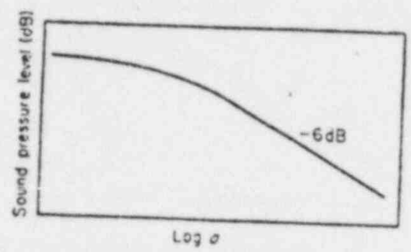

Figure 5. Sound pressure level attenuation with distance from the area source shown in Figure 4.

3. NOISE MEASUREMENTS

Measurements were made at four power stations, three with towers of 250 MW cooling capacity (A, B and C) and one with towers of 200 MW capacity (D). At each station, a radial line from the end tower of a row was chosen in the most favourable direction to avoid extraneous noise from other sources as far as possible. A Brüel and Kjær sound level meter (type 2203) with octave-band filter set and 1 in. microphone (type 4131) was used to obtain

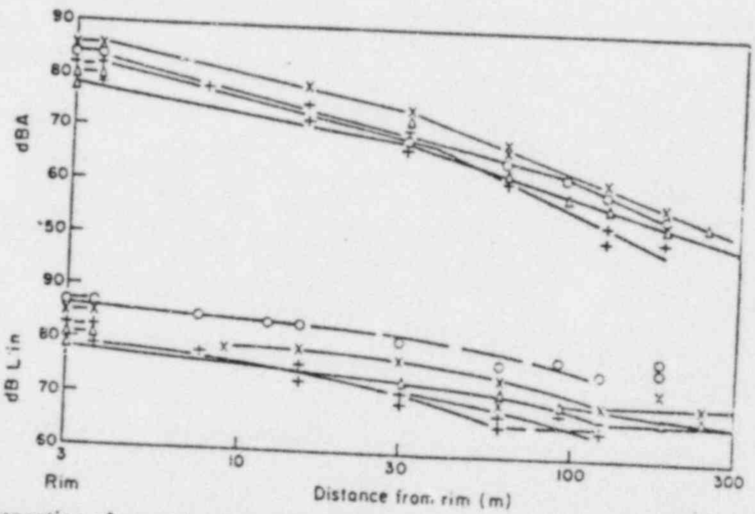

Figure 6. Attenuation of sound level A and overall sound pressure level with distance from four cooling towers. ○——○, Tower A; +——+, tower B; ×——×, tower C; △——△, tower D.

the sound levels and octave-band sound pressure levels at the rim of the pond, and at increasing distances from the rim along the radial line. The maximum distance was 183 m for A and B, 488 m for D, and 762 m for C. However, noise from extraneous sources influenced the levels at some frequencies at distances of more than about 120 m. Measurements were made under calm or very light wind conditions, and a wind-shield was used to protect the microphone from low-frequency fluctuations due to wind, but with rather limited success because of the low signal levels. The results are shown in Figures 6–9, with the levels measured at the rim of the pond shown for convenience at the 3-m position, since it was observed that there was very little change in level over the first 3 m. Figure 10 is a combination of Figures 3 and 5 drawn accurately for the two relevant values of R, namely 45·7 m for towers A, B and C, and 41·2 m for tower D.

Comparison between Figure 10 and Figures 6–9 shows good agreement between the two theories developed and the attenuations measured in practice. It can be seen that the area

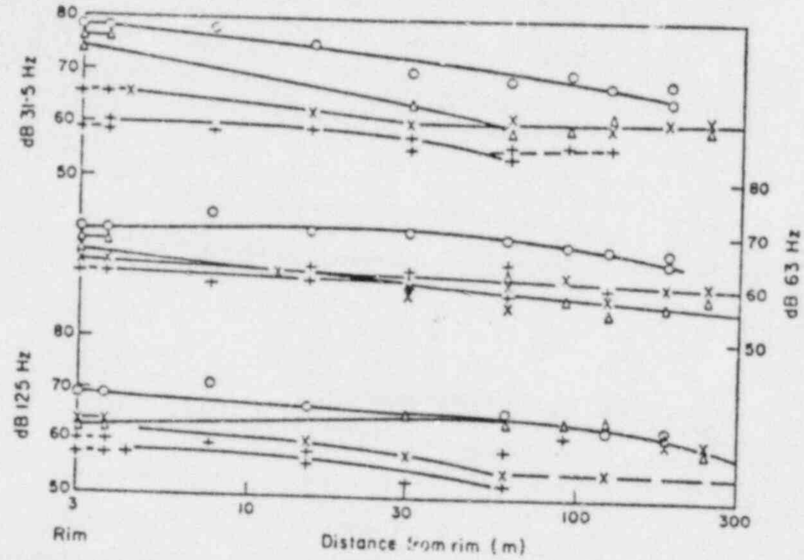

Figure 7. Attenuation of octave-band sound pressure levels with centre frequencies of 31·5, 63 and 125 Hz with distance from four cooling towers. Legend as for Figure 6.

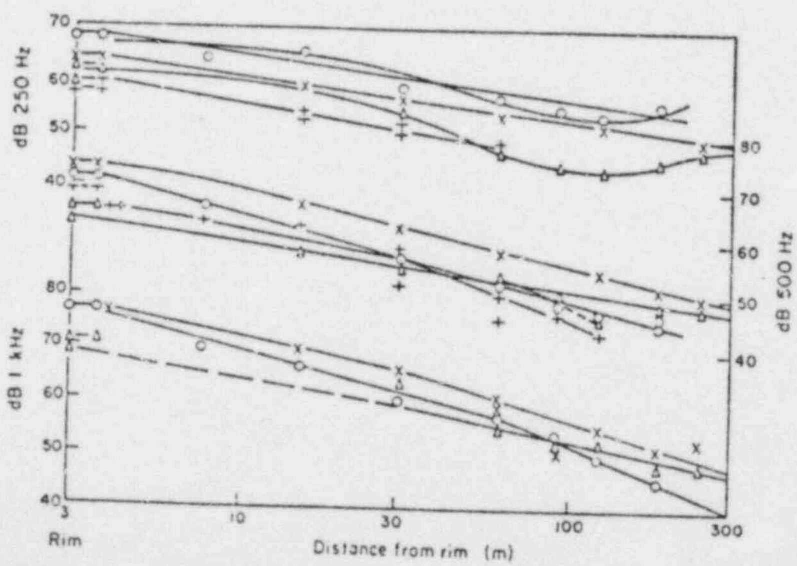

Figure 8. Attenuation of octave-band sound pressure levels with centre frequencies of 250, 500 and 1000 Hz with distance from four cooling towers. Legend as for Figure 6.

source propagation is more satisfactory for the overall sound pressure levels and octave bands up to and including that centred on 250 Hz. Above this, the arc source approach gives the more satisfactory agreement, with atmospheric absorption adding to the attenuation at 2 kHz and above. The value of R given by the change of slope of the attenuation curves was generally in the range 30–60 m.

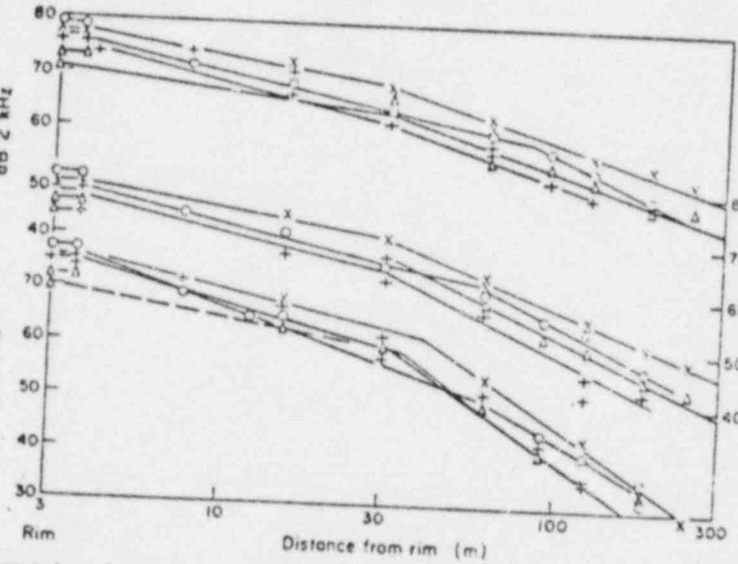

Figure 9. Attenuation of octave-band sound pressure levels with centre frequencies of 2, 4 and 8 kHz with distance from four cooling towers. Legend as for Figure 6.

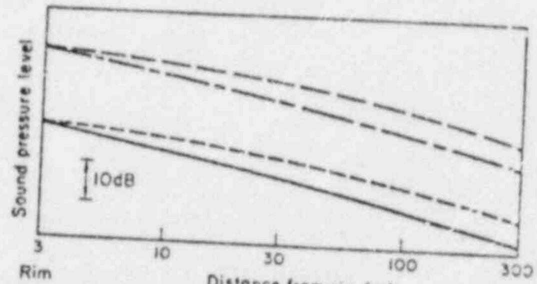

Figure 10. Theoretical attenuation of sound pressure level with distance from ring of radius 41·2 m (-—-) and 45·7 m (– — –) and from area sources of radius 41·2 m (----) and 45·7 m (–––).

TABLE 1

Calculated sound power of single cooling towers at various distances

Tower	Distance (m)	Overall sound pressure level (dB)	Overall sound power (w)	Sound power level (dB relative to 10^{-12} w)	A-weighted sound level (dBA)	A-weighted sound power (w)
A	15·2	84	3·9	125·9	74	0·33
	30·5	81	3·6	125·6	70	0·33
	122	74·5	4·7	126·7	60	0·27
B	15·2	74·5	0·44	116·4	72	0·21
	30·5	71	0·36	115·8	69	0·25
	122	64	0·42	116·2	55·5	0·10
C	15·2	80	1·55	121·9	78	0·82
	30·5	77·5	1·6	122	74	0·82
	122	70	1·7	122·3	61	0·34
D	30·5	73–75	0·52–0·82	117·2–119·1	69–71	0·24–0·38
	122	67–69	0·79–1·25	119–121	56–57	0·11–0·13

A numerical check on the validity of the two equations was made by calculating the overall sound power [using equation (4)] and A-weighted sound power [using equation (1)] from the measurements at distances of 15·2, 30·5 and 122 m. The results are given in Table 1, which shows that equation (4) gives nearly constant values for the overall acoustic power of any one tower at all three distances. Equation (1) for the A-weighted power gives similar values at 15·2 and 30·5 m for any one tower but underestimates the source power if the 122-m levels are used—presumably because of atmospheric absorption since tower A with the high levels in the lower frequencies is less affected than the other towers.

4. ACOUSTIC POWER GENERATION

It seemed logical as a first assumption to consider that the acoustic power would be directly proportional to the hydraulic power dissipated in the tower, i.e.

$$W_{ac} = \eta_{ac} Mgh, \tag{5}$$

where M is the mass flow rate of cooling water (kg/sec) and h is the distance the water falls from the culvert into the pond (in metres).

The acoustic power of the four towers was also calculated from the sound level measured at the rim of the pond, using the equation

$$W_{ac} = \frac{P^2_{rim} \times 2\pi Rh'}{Z_0}, \tag{6}$$

where h' was the depth of the "open" area below the tower shell—from pond to ring beam. A-weighted sound levels were used to eliminate spurious low-frequency levels, and because, subjectively, A-weighted levels are more useful. The results are given in Table 2, together with the relevant values of M, h and h' for the four towers. The values of A-weighted power obtained by this method agree reasonably well with those calculated from equation (1) and quoted in Table 1.

TABLE 2

Comparison of hydraulic and acoustic power, and physical properties of the four towers

Power station	A	B	C	D
Radius of tower, R (m)	45·7	45·7	45·7	41·2
Depth of packing below ring beam, T (m)	4·57	3·05	None	5·8
Height from pond to base of packing, D (m)	1·83	4·26	6·72	0·3
Cooling water flow rate, M (kg/sec)	7570	7570	8500	6800
Cooling water flow rate, M (gall/hr)	6·0	6·0	6·75	5·4
Hydraulic height, h (m)	7·93	9·3	8·84	6·4
Hydraulic power, W_h (MW)	0·59	0·69	0·737	0·427
Sound level at rim (dBA)	84	81	85	80
Open height, h' (m)	6·4	7·3	6·7	6·1
A-weighted acoustic power, W_{ac} (W)	0·45	0·26	0·60	0·16
A-weighted acoustic efficiency, W_{ac}/W_h	$0{\cdot}76 \times 10^{-6}$	$0{\cdot}38 \times 10^{-6}$	$0{\cdot}81 \times 10^{-6}$	$0{\cdot}37 \times 10^{-6}$

It can be seen that there is considerable variation in the value of η_{ac}, either because the sound powers are not accurate, or because equation (5) is not valid. A second approach was therefore tried, assuming the acoustic power to be given by an equation of the form

$$W_{ac} = Mh\left[A\left(\frac{T}{h}\right)^n + B\left(\frac{D}{h}\right)^m\right], \tag{7}$$

where T was the depth of packing below the ring beam, and D the height from the pond to the base of the packing (see Figure 1), A and B are constants with dimensions of m/sec², analogous to efficiency, and m and n are indices which were assumed to be integers. Inspection of the two terms showed that the best agreement would be given with $m = n = 2$, $A = 0{\cdot}95 \times 10^{-5}$ and $B = 1{\cdot}8 \times 10^{-5}$ m/sec. These values, when used in equation (7), gave values for A-weighted sound power of 0·25, 0·34, 0·78 and 0·34 A-watts for towers A, B, C and D, respectively.

The octave-band levels for the towers at the rim and at a distance of 30 m from the rim are shown in Figure 11. The shapes of the spectra from 0·125 to 8 kHz are very similar, peaking in the 4 kHz octave band with a value approximately 4 dB below the A-weighted sound level. Since the towers spanned the whole range of likely packing configurations and yet gave such similar spectra, it is reasonable to propose that other towers would not give significantly different spectra. The average octave-band levels relative to the A-weighted sound level at the rim and at 30 m from the rim are given in Table 3.

TABLE 3

Average octave-band levels relative to A-weighted sound level

Centre frequency (Hz)	125	250	500	1000	2000	4000	8000
Level at rim (dB)	−19·4	−19·8	−13·0	−7·8	−6·3	−4·3	−7·2
Level at 30·5 m (dB)	−10·4	−16·0	−13·0	−8·4	−5·7	−4·3	−10·8

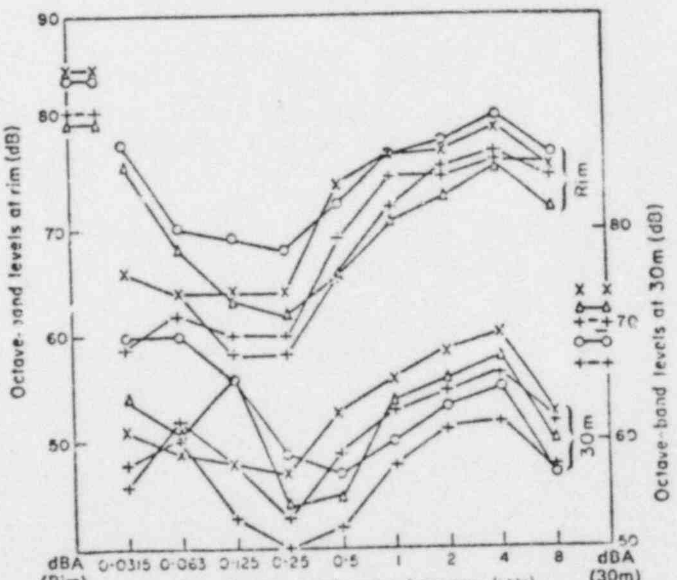

Figure 11. Octave-band spectra at the rim and at 30·5 m from the rim of the four cooling towers. Legend as for Figure 6.

5. PREDICTION METHOD

From the data presented in this paper, it is now possible to detail a complete prediction method for the noise from cooling towers whose constructional details are known.

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Tower F

The stages are as follows.

(1) Calculate the A-weighted acoustic power from the equation

$$W_{ac} = Mh\left[0{\cdot}95 \times 10^{-5}\left(\frac{T}{h}\right)^2 + 1{\cdot}8 \times 10^{-5}\left(\frac{D}{h}\right)^2\right].$$

(2) The A-weighted sound level at the rim of the pond can be found from

$$P^2_{rim} = \frac{W_{ac} \times Z_0}{2\pi Rh'},$$

and the octave-band levels found from Table 3.

(3) The A-weighted sound level at a distance a from the rim can be found from

$$P^2_A = \frac{W_{ac} \times Z_0}{\pi^2(a^2 + 2aR)} \tan^{-1} \sqrt{\left[\frac{a + 2R}{a}\right]},$$

and the octave-band levels again found from Table 3.

For distances greater than 30 m, it is suggested that the spectrum shape at the rim be used, and that the octave-band levels should be further corrected for atmospheric absorption using the following data [1].

Centre frequency (Hz)	500	1000	2000	4000	8000
Atmospheric absorption (dB/300 m)	0·7	1·4	3·0	7·7	14·4

The corrected octave-band levels so obtained can then be used to calculate the true A-weighted sound level, if desired.

Using this method, the levels were predicted for two further towers. One, tower E, had packing right down to the surface of the pond, and a nominal cooling capacity of 35 MW. The other, tower F, was of nominal capacity 120 MW, and the packing stopped 0·5 m above the ring beam (i.e. $T = 0$). They thus represented two extremes of design, and would put the method to a severe test. The predicted levels are shown in Table 4, together with the levels that were actually measured. The agreement is seen to be remarkably good, suggesting that this is a powerful technique for prediction.

TABLE 4

Comparison of measured and predicted levels for towers E and F

Position		dBA	Octave-band sound pressure levels (dB relative to 2×10^{-5} N/m²)						
			125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Tower E. Rim	Predicted	81·2	61·6	61·4	68·2	73·4	74·9	76·9	74
	Measured	81	61	58	67	73·5	74·5	76·5	75·5
		81	61	58	67	73	74·5	76·5	75
Tower E. 15·2 m	Predicted	70·4	56·5	52·5	57·4	62·3	64·4	66·1	61·4
	Measured	70	54	49	54	61	64	65·5	63·5
		71	60	49	55·5	61·5	64·5	66·5	64·5
Tower E. 30·5 m	Predicted	66·1	55·7	50·1	53·1	57·7	60·4	61·8	55·3
	Measured	66	55	48	51	59	60·5	61·5	58
		66·5	61	49	50	58	59·5	62·5	59·5
Tower F. Rim	Predicted	84·2	64·8	64·4	71·2	76·4	77·9	79·9	77
	Measured	85	64	66	74	77	77	80	78·5

As a final check, the levels from the array of 250 MW towers shown in Figure 12 were estimated at the points shown, and compared with the measured levels. Again, agreement was excellent right out to 805 m from the nearest working tower (position 5). The detailed calculations are shown in the Appendix, together with the measured levels.

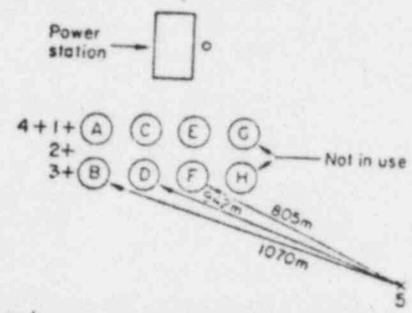

Figure 12. Cooling tower layout and measurement positions at a 2000 MW power station.

6. CONCLUSIONS

A method has been devised, based on measurements made on four large cooling towers, for predicting the acoustic power output from natural-draught cooling towers, and for estimating the A-weighted sound levels and octave-band sound pressure levels at considerable distances from them. The method was used to predict the levels from three further towers and gave excellent agreement with the measured values.

ACKNOWLEDGMENT

The work was carried out at the Central Electricity Research Laboratories, and the paper is published by permission of the Central Electricity Generating Board.

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APPENDIX

Calculations of the A-weighted sound power of the cooling towers shown in Figure 12, and the A-weighted sound level and octave-band sound pressure levels at the rim of the tower and at the five points shown.

CALCULATION OF A-WEIGHTED SOUND POWER

Each tower had a water flow rate of 112.500 gal/min from a culvert 38 ft above the level of the pond. The packing was 27 ft thick and extended right down to the pond. The open height was 26 ft and the radius of the tower 155 ft (47·2 m).

In addition 20,000 gal/min of warm water was used for de-icing and was sprayed from a pipe which ran around the perimeter of the tower 3 ft below the ring beam, directly downwards into the pond which was 24 ft below.

Thus the data in metric units [which must be used for the values of A and B of equation (7)] are as follows.

Tower Water

$M = 112{,}500$ gal/min $= 8500$ kg/sec,

$h = 38$ ft $= 11{\cdot}6$ m, $h' = 26$ ft $= 7{\cdot}92$ m, $T = 27$ ft $= 8{\cdot}22$ m, $D = 0$ ft.

$$W_{ac} = 8500 \times 11{\cdot}6 \times 0{\cdot}95 \times 10^{-5}\left(\frac{8{\cdot}2}{11{\cdot}6}\right)^2 = 0{\cdot}473 \text{ A-watts.}$$

De-icing Water

$M = 20{,}000$ gal/min = 1510 kg/sec,

$h = D = 24$ ft = 7·32 m,

$W_{ac} = 1510 \times 7{\cdot}32 \times 1{\cdot}8 \times 10^{-5} \times 1^2 = 0{\cdot}199$ A-watts,

$\therefore$ total acoustic power of each tower = 0·672 A-watts.

SOUND LEVELS AND OCTAVE-BAND SOUND PRESSURE LEVELS

At rim of pond

$$P_A^2 = \frac{W_{ac} \times Z_0}{2\pi R h} = \frac{0{\cdot}672 \times 407}{2\pi \times 47{\cdot}2 \times 7{\cdot}92} = 0{\cdot}1165\ (\text{N/m}^2)^2,$$

$$\therefore P_A = 0{\cdot}341 \text{ N/m}^2 = 84{\cdot}7 \text{ dBA.}$$

From Table 3 we obtain the following octave-band levels.

Centre frequency (kHz)	0·125	0·250	0·500	1	2	4	8	dBA
Predicted levels (dB)	65·3	64·9	71·7	76·9	79·4	80·4	77·5	84·7
Measured levels (dB)	65	63	72	77·5	78·5	80·5	79·5	85

30·5 m from rim of pond—positions 1 and 3.

$$P_A^2 = \frac{W_{ac} \times Z_0}{\pi^2(a^2 + 2aR)} \tan^{-1} \sqrt{\left[\frac{a + 2R}{a}\right]}$$

$$= \frac{0{\cdot}672 + 407}{\pi^2(930 + 2880)} \tan^{-1} \sqrt{4{\cdot}1} = 0{\cdot}00808\ (\text{N/m}^2)^2,$$

$$P_A = 0{\cdot}09 \text{ N/m}^2 = 73{\cdot}1 \text{ dBA.}$$

Again from Table 3, we obtain the following:

Centre frequency (kHz)	0·125	0·250	0·500	1	2	4	8	dBA
Predicted levels (dB)	62·7	57·1	60·1	64·7	67·4	68·8	62·3	73·1
Measured at position 1	64	58	59	63·5	65	68	64·5	72
Measured at position 3	64	52	58	64	65·5	69	65·5	72

At position 2, 64 m (210 ft) from towers A and B. (The contributions to the sound levels from the rest of the towers will be negligible.)

$$P_A^2 = \frac{0{\cdot}672 \times 407}{\pi^2(4100 + 6080)} \tan^{-1} \sqrt{2{\cdot}47} = 0{\cdot}00273\ (\text{N/m}^2)^2 \qquad (P_A = 0{\cdot}052 \text{ N/m}^2)$$

$$= 68{\cdot}4 \text{ dB.}$$

The octave-band levels will be

Centre frequency (kHz)	0·500	1	2	4	8	dBA
Predicted levels from tower A	55·4	60·6	62·1	64·1	61·2	(68·4)
Atmospheric absorption	−0·1	−0·3	−0·6	−1·6	−3·0	
Contribution from tower B	3	3	3	3	3	
Total predicted levels at position 2	58·3	63·3	64·5	65·5	61·2	69·6
Measured at position 2	53	62·5	64·5	65	59	69

At position 4, 122 m from tower A and 183 m from tower B, using the same procedure as above, the predicted octave-band levels are given below.

Centre frequency (kHz)	0·500	1	2	4	8	dBA
Predicted levels from tower A	50·6	55·5	56·4	56·5	50·7	
Predicted levels from tower B	47·5	52·3	52·8	52·0	45·1	
Total predicted levels at position 4	52·3	57·2	58·0	57·8	51·7	63·3
Measured levels at position 4	50	56·5	58	58	47	63

At position 5, it is assumed that the total noise levels will be due to contributions from towers B, D and F and that towers A, C and E will be masked.

Centre frequency (kHz)	0·500	1	2	4	8
Predicted levels from tower F	34·1	37·5	34·4	24·8	—
Predicted levels from tower D	32·4	35·5	32·0	19·5	—
Predicted levels from tower B	31·1	33·9	29·8	15·3	—
Total predicted levels at position 5	37·5	40·7	37·5	26·0	—
Measured levels at position 5	39	40	37	24	—

N.B. All levels quoted are in dB relative to 2×10^{-5} N/m^2.

ENVIRONMENTAL NOISE IMPACT OF
NATURAL DRAFT HYPERBOLIC COOLING TOWERS

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Protection of the natural environment may necessitate consideration of alternate cooling systems for some electric power generating stations to reduce the temperature and amount of cooling water discharged. The impact of the sound emitted by cooling towers on the surrounding community is one of the elements considered in the benefit-cost analysis of alternate cooling systems. This paper (1) summarizes the results of field measurements used to quantify the sound emission from natural draft hyperbolic cooling towers (2) develops a simplified cooling tower noise emission prediction scheme, and (3) evaluates the impact of the noise emission on the surrounding community. The study has been limited,however, to the range of cooling towers considered for electric utility applications.

A. Cooling Tower Description

Two types of natural draft hyperbolic cooling towers were considered in this study - crossflow and counterflow. In the crossflow tower, Figure 1, the hot water from the power plant, which is to be cooled, is delivered to the top of a cylindrical annulus external to the base of the tower. This hot water is distributed around the tower and falls through multiple tiers of fill creating droplets of water. The impingement of these water droplets on the fill material and on the water in the basin below are the primary noise generating mechanisms. Draft cooling air passes by the droplets at an angle of about 90 degrees, hence, the crossflow designation. The cooled water is then collected in the basin at the base of the tower and returned to the plant. In the counterflow tower, Figure 2, the hot water is pumped to a a distribution system above the fill, and runs through the fill. The water then falls from the fill to the collecting basin in the form of droplets. These droplets impacting the water in the basin is the primary source of noise generation. Draft cooling air enters the tower between the water collecting basin and tower shell, and passes through the water droplets in a direction counter to their flow (180°). The cooled water is collected in the basin at the base of the tower and then returned to the plant.

B. Noise Measurement and Analysis

Techniques for estimating sound emissions from natural draft towers have been previously published by Ellis.[1] In order to validate this prediction scheme, noise measurements[2] of the sound emitted by both counterflow and crossflow cooling towers were made at several electric generating stations in the eastern half of the country.

An A-weighted sound level analysis was deemed sufficient for development of a sound emission prediction scheme and for evaluating subjective community response, since the sound generated by water falling in both types of towers is continuous, and the frequency spectra is broad-band and generally without tones. A summary of the natural draft hyperbolic cooling tower noise measurements made at power plants is shown in Table I, and the typical range of octave band spectra is shown in Figure 3. For the cooling towers that were evaluated, the Ellis prediction scheme appears to be conservative, i.e., this scheme estimates sound levels to within 3 dB(A) of the measured sound levels at 40 feet and 80 feet

Sound levels measured in the near field of the cooling towers were normalized to a common water flow rate, by adding or subtracting ten times the logarithm of the difference between the rated and common water flow rates from the sound levels measured at similar distances from the tower basin rim. Results therefore indicate, that for similar water flow rates, the A-weighted sound level for counterflow towers was about 1 dB(A) higher than crossflow towers.

Since the noise generating mechanisms and emission levels of the two types of cooling towers differ, two equations for estimating near field sound emissions at a distance of 40 feet from the basin rim were developed. The 40 foot distance was selected since it is in the near field of the tower, and the sound level measured would not be significantly altered by structural elements of the tower. Sound levels measured at 40 feet were normalized to the tower's water loading, by subtracting from the measured sound levels, ten times the logarithm of the water loading. Water loading is determined when the cooling water flow rate (M), in G.P.M., is divided by the active (or working) tower area (A), in square feet, receiving the water droplets. The results of normalizing the measured values shown on Figure 4, indicate the parametric dependency of sound emissions upon water loading. For the range in size of cooling towers investigated, our studies indicate that water loading is the significant parameter which determines sound emissions. For practical purposes, the active area of a cooling tower is considered the area of the water basin for counterflow towers and the mean area of the fill for crossflow towers. Based upon the noise measurements and the effect of water loading on noise emissions, the A-weighted sound level at 40 feet from the rim of the water basin can be simply estimated by the following two equations: (Figure 5)

$L_{40} = 71 + 10 \log(M/A)$, db(A) for crossflow towers (Eqn. 1)

and,

$L_{40} = 75.5 + 10 \log(M/A)$, dB(A) for counterflow towers (Eqn. 2) where; L_{40} - A-weighted sound level at 40 feet

M - water flow rate in G.P.M.

A - active area of the tower in Ft^2

Divergence of sound to the far field was calculated using the two equations presented in Reference 1 for typical power plant natura draft hyperbolic cooling towers. Sound attenuation as a function of distance from the cooling tower is shown on Figure 6. Excess air attenuation for a typical situation was additionally estimated using the cooling tower sound spectrum and was added to divergence as shown again on Figure 6. As expected, cooling tower sound attenuated at the rate of 3 dB for doubling distance in the near field, and 6 dB for doubling distance in the far field.

Table II compares measured sound levels with sound levels estimated by the method developed herein. Estimated sound levels at 40 feet and 80 feet, and in the far field, are within the equivalent accuracy found using the Ellis method for the range in size of towers studied. For the type of cooling towers studied, and others in operation or planned for future operation, variance in air inlet height, fill, and basin diameter would introduce about a maximum 1 dB(A) variance in noise emissions. In summary, water loading has been found by our study to be the significant parameter determining noise emissions from natural draft hyperbolic cooling towers.

Cooling towers are generally set-back considerable distances from the plant property line or nearest residential neighbor. Excess attenuation due to factors such as changes in atmospheric sound absorption, natural barriers, meteorology, vegetation, etc. may be factors in calculating the expected community noise intrusion, and have not been included in the discussion since they are unique to each site. Therefore, daily cooling tower community noise intrusion can at best be represented by an expected range of levels due to variations in multiple factors that contribute to excess attenuation.

C. Community Noise Evaluation

In order to evaluate the environmental impact of sound emitted by a natural draft cooling tower on surrounding residential communities, two alternate schemes were used - one was to calculate the Day-Night averaged A-weighted sound level, L_{dn}, as proposed by the Federal Environmental Protection Agency,[3] and the second was to calculate the Noise Pollution Level in dB(A), L_{NP}, as proposed by Robinson.[4]

Electric utilities, unlike other industries, are required to provide continuous uninterupted service, twenty-four hours per day. Therefore, cooling towers, by necessity, operate continually. Based upon the E.P.A.'s residential community noise criteria of L_{dn} = 55 dB, cooling tower noise emitted into a community, would be limited to about 49 dB(A) exclusive of the presence of background noise, since the calculated L_{dn} for a continuous noise source is 6.4 dB higher than its continuous measured A-weighted sound level.

However, when the cooling tower noise emissions are superimposed on the background noise level measured in a typical surburban New York community, the results are shown in Table III. It can be observed from Table III, for the two communities studied, that near to the cooling tower, the noise emitted by the tower would control the sound heard by the community. At distances farther away from the tower and well into the community, the community background noise becomes the significant sound contributor. A typical example of siting a natrual draft cooling tower servicing a power plant is illustrated on Figure 7. Based upon this example, an acoustical buffer zone of 5,000 feet is required to achieve an $L_{dn} = 55$dB with consideration of the community's background noise. In some cases, the cumulative effect of noise emissions from both the power plant and the cooling tower may necessitate a larger buffer zone, since the noise emissions of the power plant may be the same order of magnitude as the noise emissions from the cooling tower.

An alternate method of estimating environmental impact is to compute the Noise Pollution Level, as proposed by Robinson for traffic oriented noise intrusion:

$$L_{NP} = L_{50} + \frac{1}{56} (L_{10} - L_{90})^2 + 1.55 (L_{10} - L_{90}), \text{ dB(A)} \quad \text{Eqn. (3)}$$

Computation of the L_{NP} for the quiet suburban residential community is shown on Table IV. The results suggest that, for the community investigated, the introduction of a continuous steady sound level can reduce the community's Noise Pollution Level because of the reduction in the variation between the residual and intrusive noise levels (those levels exceeded for 90% and 10% of the time respectively), as the mean noise level (noise exceeded 50% of the time) increases. As the steady sound introduced increases beyond the ambient intrusive (L_{10}) level, the L_{NP} also starts to increase. Thus, for each community there may be an optimal sound intrusion level that minimizes L_{NP}. For the quiet community studied, a continuous intrusion of 45 dB(A) appears to be optimal. From a practical viewpoint, the introduction of broadband continuous sound from a source such as natural draft cooling towers may be beneficial by providing acoustical masking for the continuous tones generated by that station's power transformers, or the intermittent sounds such as steam venting.

D. Conclusion

In conclusion, our studies have shown that noise emitted by the type of natural draft hyperbolic cooling towers commonly used for power plant application can be predicted at distances of 40 feet or more from the basin rim, using the simplified method which was developed from measured data and published results. Cooling tower noise emissions appear to be most directly related to water loading. However, noise levels predicted in the far field, possibly impacting the community, are influenced by those environmental factors controlling excess attenuation

The study further suggests that significant amounts of noise control cannot be achieved by modifying the physical parameters of natural draft cooling towers, as presently designed. Finally, the environmental impact of natural draft cooling tower sound emissions can be minimized if sufficient distance is provided between the cooling tower and the neighboring community to attenuate the cooling tower noise.

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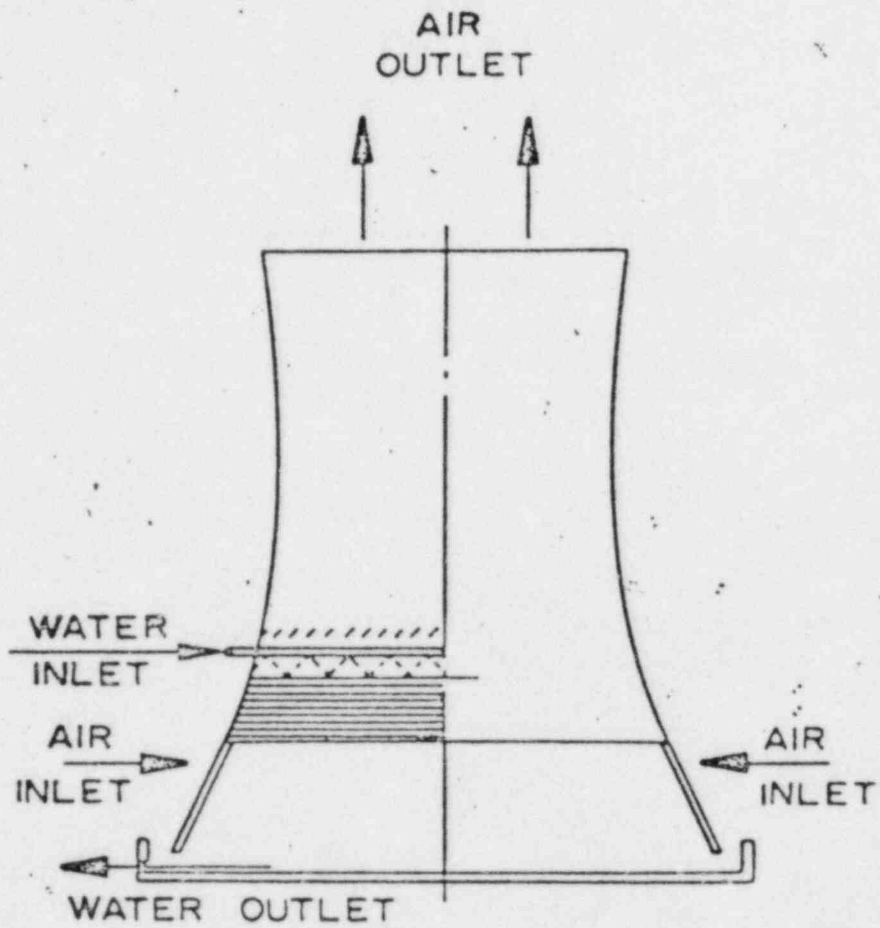
2. Ostergaard Associates Report 1111 A-7 (draft), prepared for Con Edison, February 15, 1974.

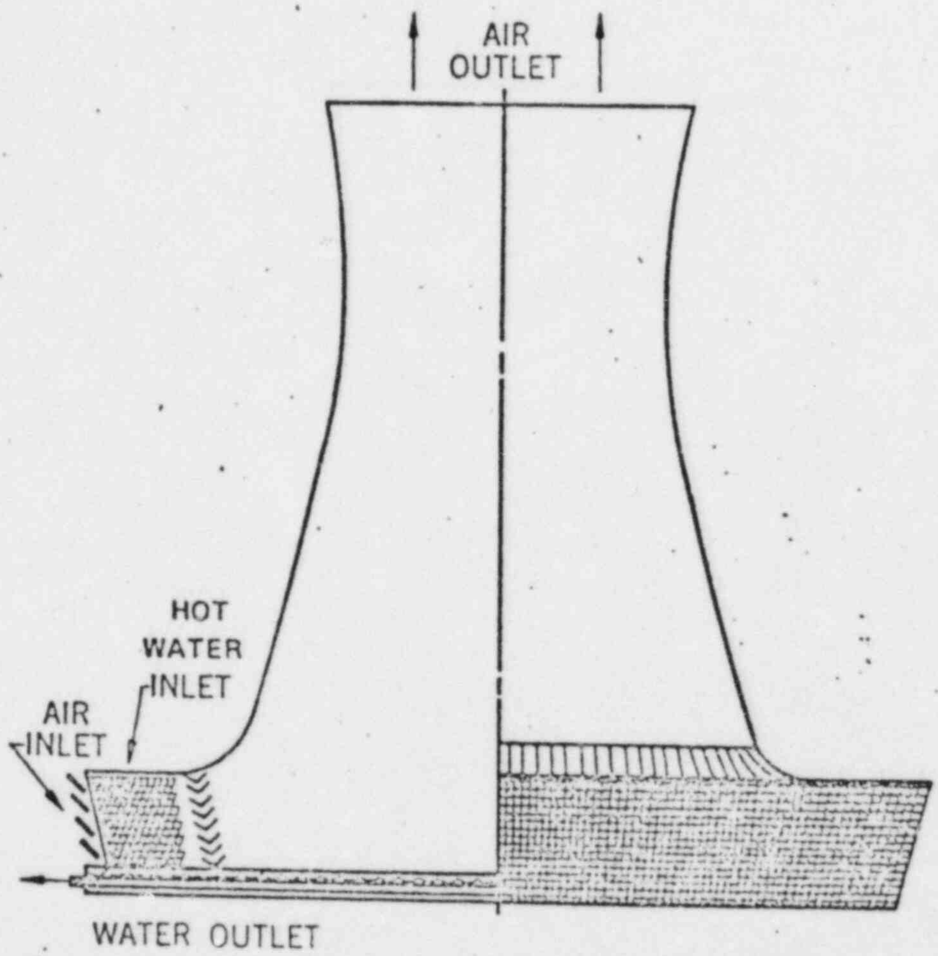
3. "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with Adequate Margin of Safety," Environmental Protection Agency, March 1974.

4. "Towards a Unified System of Noise Assessment," D. W. Robinson, Journal of Sound and Vibration (1971) 14 (3) pp. 274-298.



NATURAL - DRAFT WET COOLING TOWER
(COUNTER - FLOW)

Figure 1



NATURAL - DRAFT WET COOLING TOWER
(CROSS - FLOW)

Figure 2

TABLE I

COMPARISON OF MEASURED AND PREDICTED SOUND LEVELS
FOR NATURAL DRAFT COOLING TOWERS
Sound Level in dB(A)

Distance from Tower (feet)			40'		80'		320'		640'	
Tower No.	Flow Rate (GPM)	Type	Measured	Ellis[1]	Measured	Ellis[1]	Measured	Ellis[1]	Measured	Elli
1	1.39×10^5	Counterflow	79	81	75	76	*	65½	*	
2	1.40×10^5	Counterflow	80½	79½	76½	75	*	64½	*	
3	2.50×10^5	Counterflow	80	83½	77	78½	*	68½	*	
4	2.64×10^5	Crossflow	81	83	76	78	66	68½	60	61½
5	2.31×10^5	Crossflow	80	81½	75	77	63	66½	54	60

* Plant Noise Emissions or Topographical Conditions Prevented Accurate Measurements.

[1] With Air Absorption 50°F & 55% RH.

TABLE II

COMPARISON OF MEASURED AND PREDICTED SOUND LEVELS
FOR NATURAL DRAFT COOLING TOWERS
Sound Level in dB(A)

Distance from Tower (feet)			40'		80'		320'		640'	
Tower No.	Flow Rate (GPM)	Type	Measured	Pred.	Measured	Pred.	Measured	Pred.	Measured	Pred.
1	1.39×10^5	Counterflow	79	79	75	76	*	66	*	59
2	1.40×10^5	Counterflow	80½	80	76½	77	*	67	*	60
3	2.50×10^5	Counterflow	80	80½	77	75½	*	65½	*	58½
4	2.64×10^5	Crossflow	81	81	76	78	66	68	60	61
5	2.31×10^5	Crossflow	80	80	75	77	63	67	54	60

* Plant Noise Emissions or Topographical Conditions Prevented Accurate Measurements

Table III

Calculated L_{dn} for Cooling Tower Sound Intrusion

into Suburban Community

	Computed L_{dn}	
Community Sound Level plus steady sound intrusion	Community near highway	Quiet Community
Community Ambient Sound Level	58 dB(A)	52 dB(A)
Ambient + 40 dB(A) intrusion	58	53
Ambient + 45 dB(A) intrusion	59.5	54.5
Ambient + 50 dB(A) intrusion	61	57.5
Ambient + 55 dB(A) intrusion	63.5	61.5
Ambient + 60 dB(A) intrusion	67	66.5

Table IV

Calculated L_{NP} for Cooling Tower Sound

Intrusion into Quiet Suburban Community

Community Sound Level	A-Weighted Sound Level Exceed for % of time			L_{NP}
	90%	50%	10%	
Ambient	36	40	44	53.5 dB(A)
Ambient + 40dB(A) intrusion	41	43	46	51
Ambient + 45dB(A) intrusion	45	46	47.5	50
Ambient + 50dB(A) intrusion	50	50	51	52
Ambient + 55dB(A) intrusion	55	55	55	55

Acoustical Impact of Cooling Towers

Greg Capano
Wayne E. Bradley
Stone & Webster Engineering Corporation
Boston, Massachusetts 02107

Stone & Webster

PRESENTED AT THE 87TH MEETING OF THE
ACOUSTICAL SOCIETY OF AMERICA
APRIL 23-26, 1974
NEW YORK, N.Y.

PREDICTION OF "A" WEIGHTED AND OCTAVE BAND SOUND PRESSURE LEVELS FOR WET NATURAL DRAFT COOLING TOWERS

The data shown in the Sound Level Prediction Figure represents the upper limit of actual field measurements of Sound Levels in dB(A) versus Distance for eight wet-natural draft cooling towers with water capacity ranging from 140,000 to 600,000 gallons per minute. The measured sound levels did not vary directly with increase in water capacity but fell randomly on or slightly below the solid line curve in the Sound Level Prediction Figure for distances up to 1000 feet. Beyond 1000 feet, the data has been extrapolated using hemispherical radiation (6dB/double distance) and atmospheric absorption for standard conditions of 59°F and 70% relative humidity.

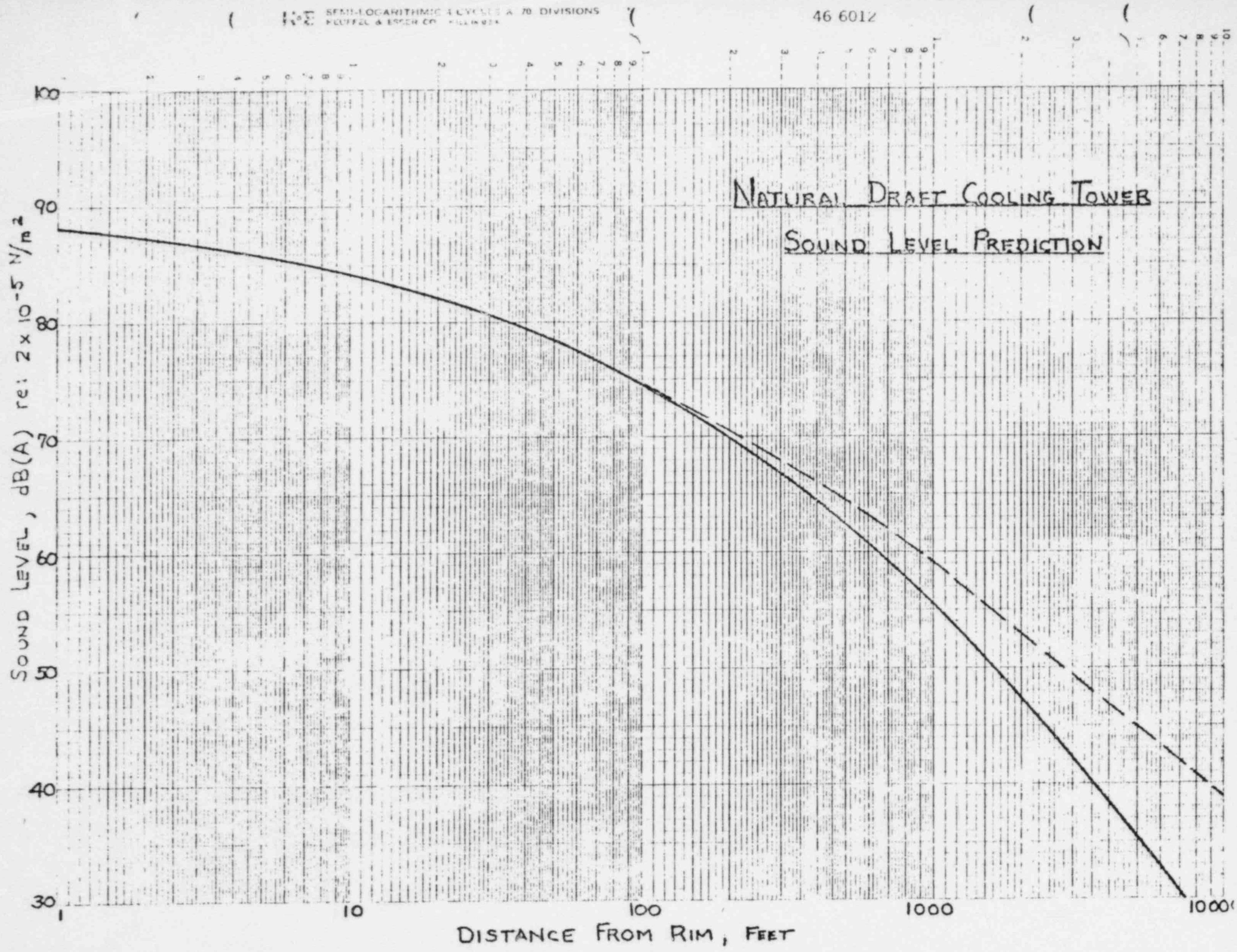
The "A" weighted sound level for a specific distance from the rim of a cooling tower is obtained directly from the solid line curve in the Sound Level Prediction Figure. The octave band sound pressure levels are obtained by using the following procedure:

A. FOR DISTANCE UP TO 100 FEET - Read directly from solid curve the "A" weighted sound level. The octave band sound pressure levels are obtained by subtracting from the "A" weighted value the average correction factors shown in Table A.

B. FOR DISTANCES BEYOND 100 FEET - Read directly from the dashed line curve, the sound level without atmospheric absorption. The octave band sound pressure levels are obtained by subtracting the average correction factors shown in Table A and by further correcting for atmospheric absorption using the following data. (Reference 4)

Center Frequency Hz	500	1K	2K	4K	8K
Atmospheric Absorption (dB/1000 feet)	0.7	1.4	3.0	7.7	14.4

The resulting octave band sound pressure levels when "A" weighted will equal the values shown by the solid line curve which represents the true "A" weighted level at that distance.


K&E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO.
46 6012
NATURAL DRAFT COOLING TOWER
SOUND LEVEL PREDICTION
SOUND LEVEL, dB(A) re: 2 x 10⁻⁵ N/m²
100
90
80
70
60
50
40
30
1
10
100
1000
10000
DISTANCE FROM RIM, FEET

NATURAL DRAFT COOLING TOWERS
50 FT SOUND PRESSURE LEVELS

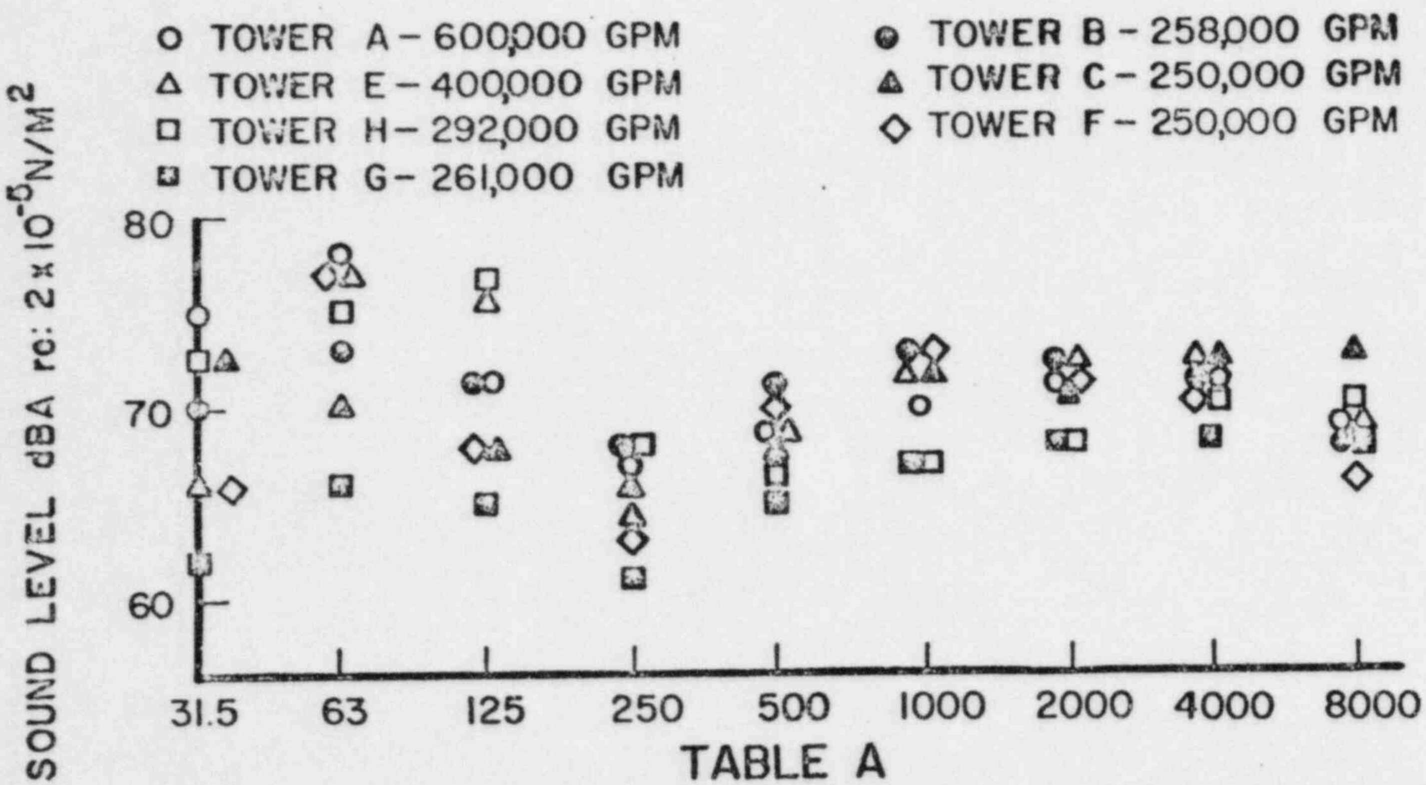
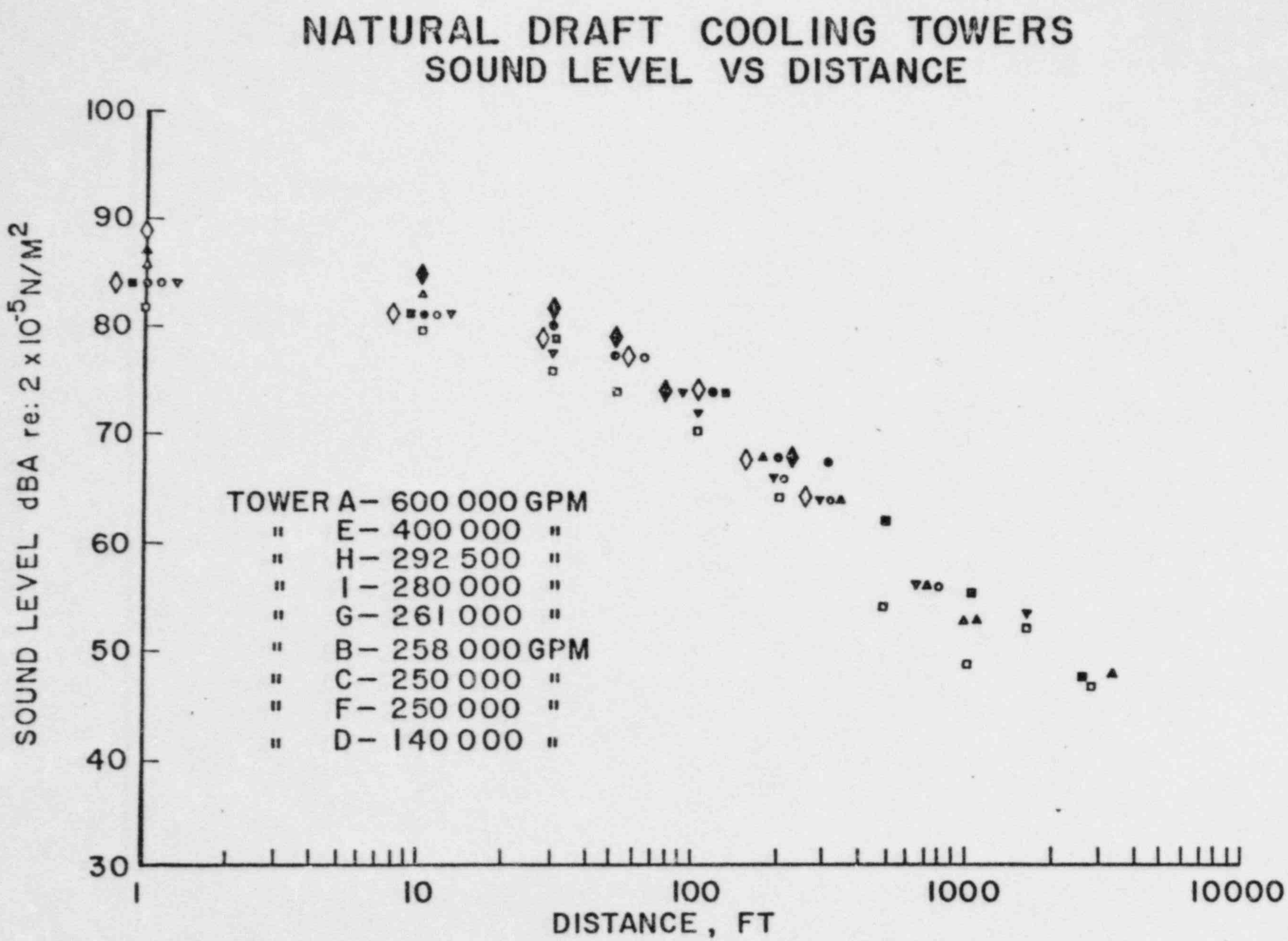


TABLE A

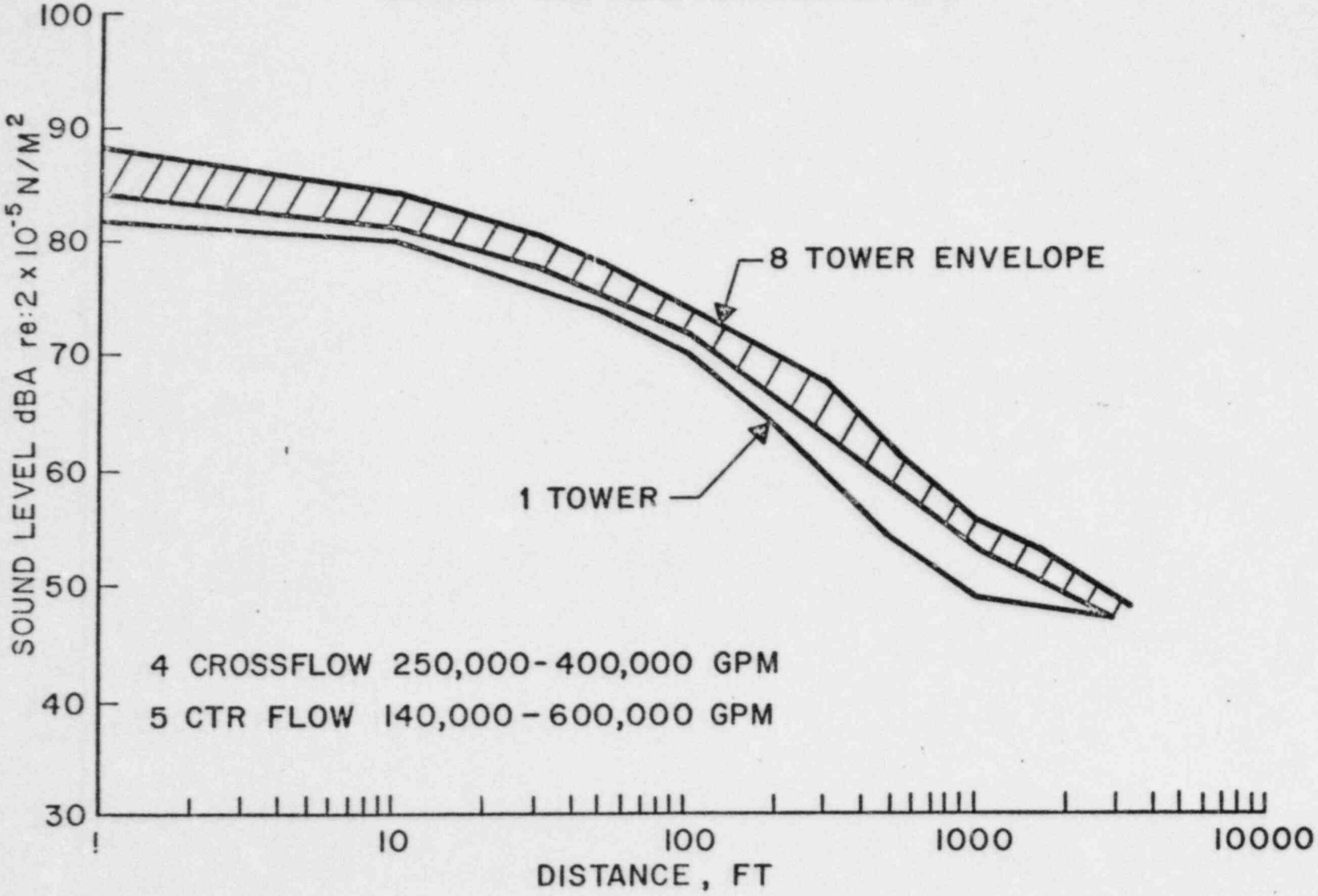
AVERAGE OCTAVE BAND LEVELS RELATIVE TO A-WEIGHTED SOUND LEVEL

CENTER FREQ (HZ)	31.5	63	125	250	500	1000	2000	4000	8000
dB CORRECTION	−6.8	−3.3	−6.3	−10.8	−8.8	−6.3	−6.8	−6.3	−8.3

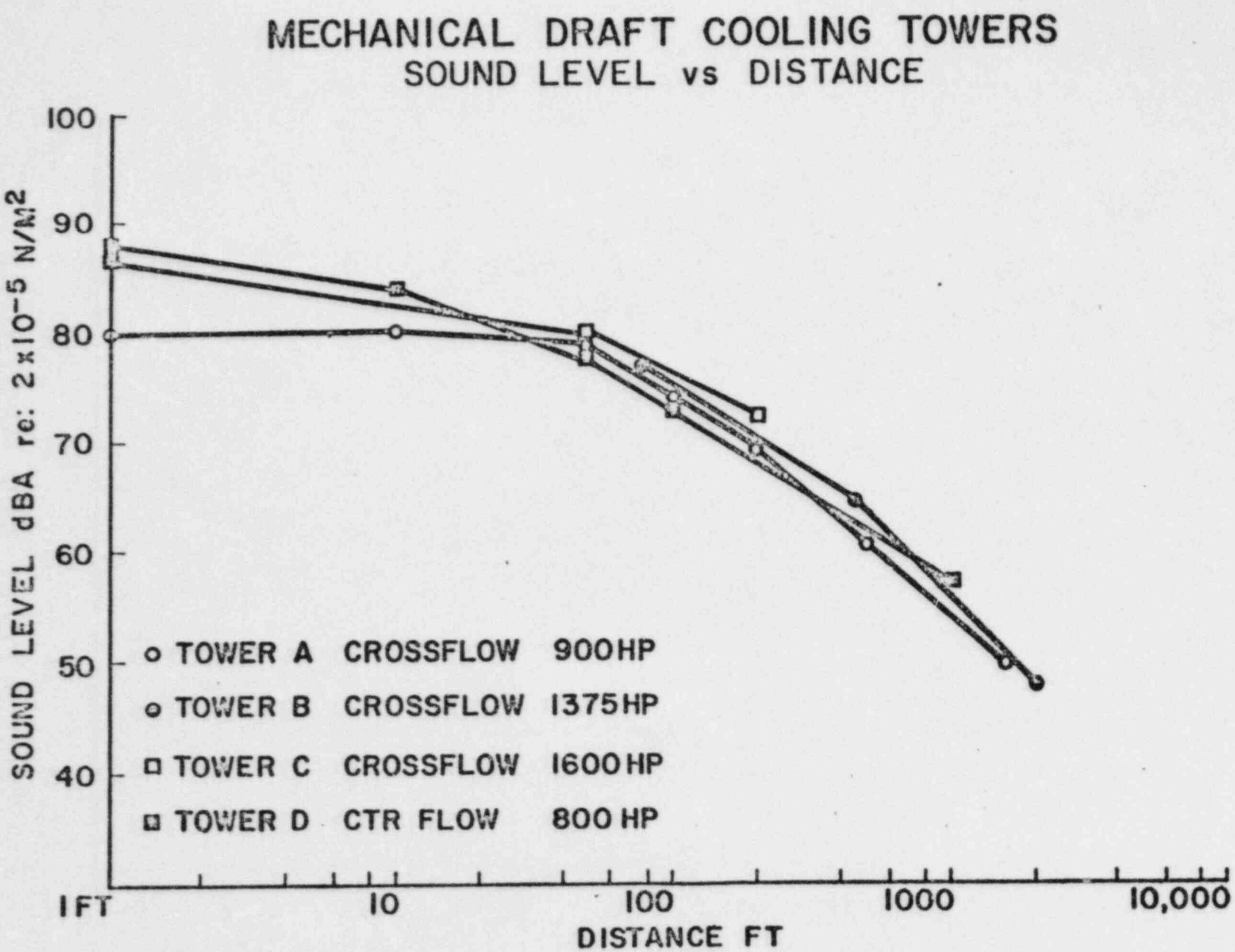


NATURAL DRAFT COOLING TOWERS
SOUND LEVEL VS DISTANCE
SOUND LEVEL dBA re: 2 x 10^-5 N/M^2
100
90
80
70
60
50
40
30
1
10
100
1000
10000
DISTANCE, FT
TOWER A- 600 000 GPM
" E- 400 000 "
" H- 292 500 "
" I- 280 000 "
" G- 261 000 "
" B- 258 000 GPM
" C- 250 000 "
" F- 250 000 "
" D- 140 000 "
74-2695

NATURAL DRAFT COOLING TOWERS SOUND LEVEL ENVELOPES

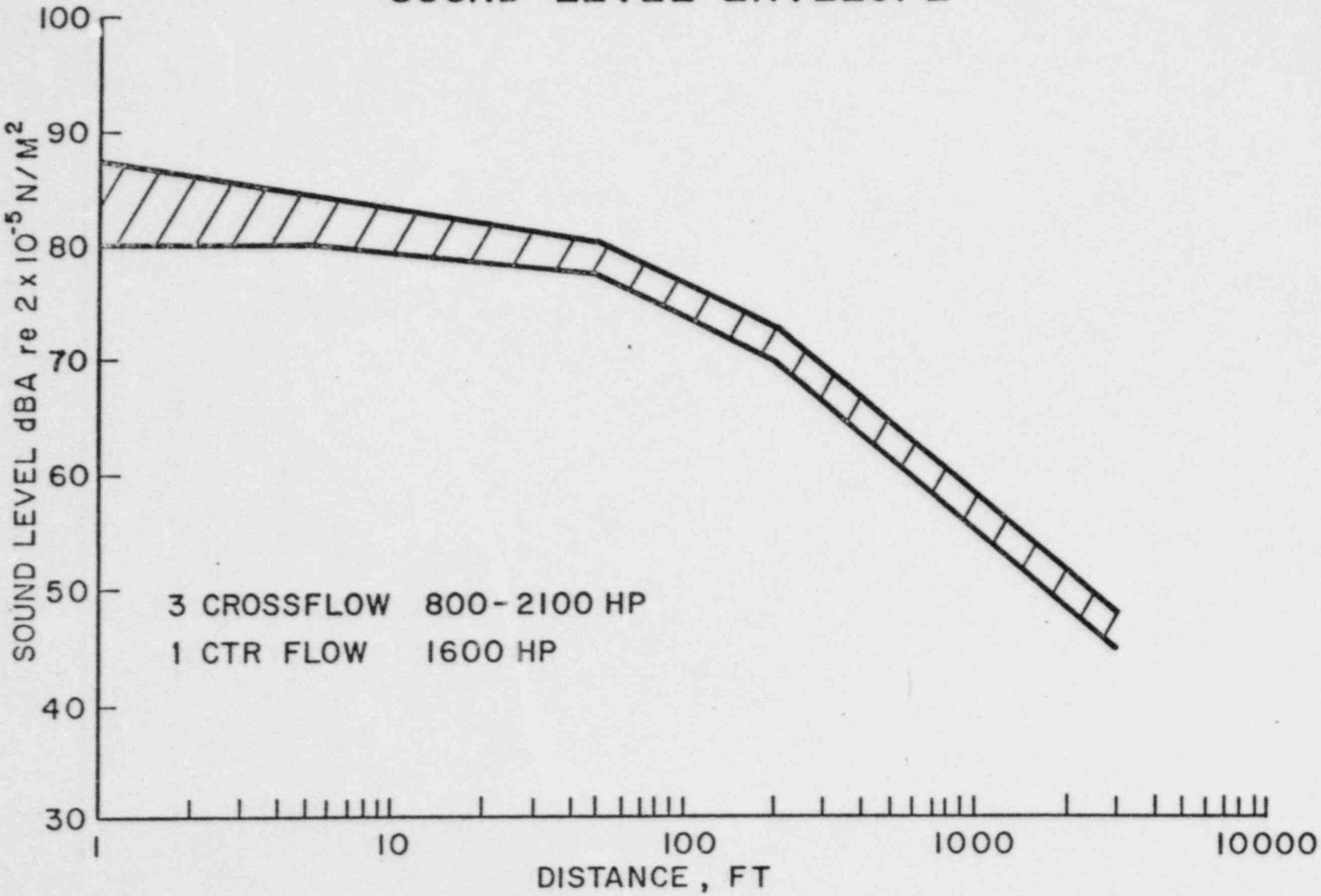


74-2693


MECHANICAL DRAFT COOLING TOWERS
SOUND LEVEL vs DISTANCE
SOUND LEVEL dBA re: 2x10^-5 N/M^2
100
90
80
70
60
50
40
o TOWER A CROSSFLOW 900HP
o TOWER B CROSSFLOW 1375HP
□ TOWER C CROSSFLOW 1600HP
□ TOWER D CTR FLOW 800HP
1FT
10
100
1000
10,000
DISTANCE FT

74-2698

MECHANICAL DRAFT COOLING TOWERS
SOUND LEVEL ENVELOPE



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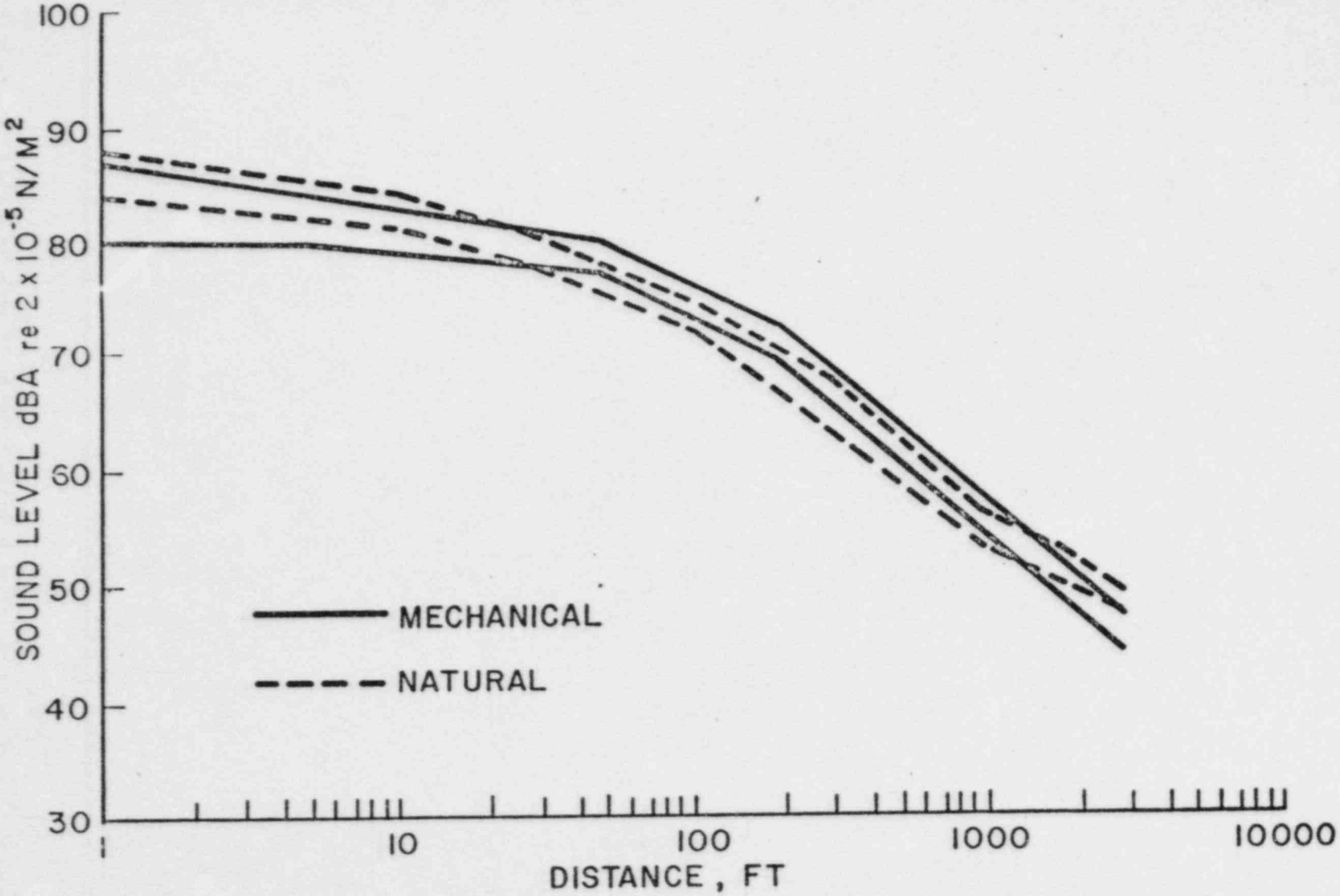
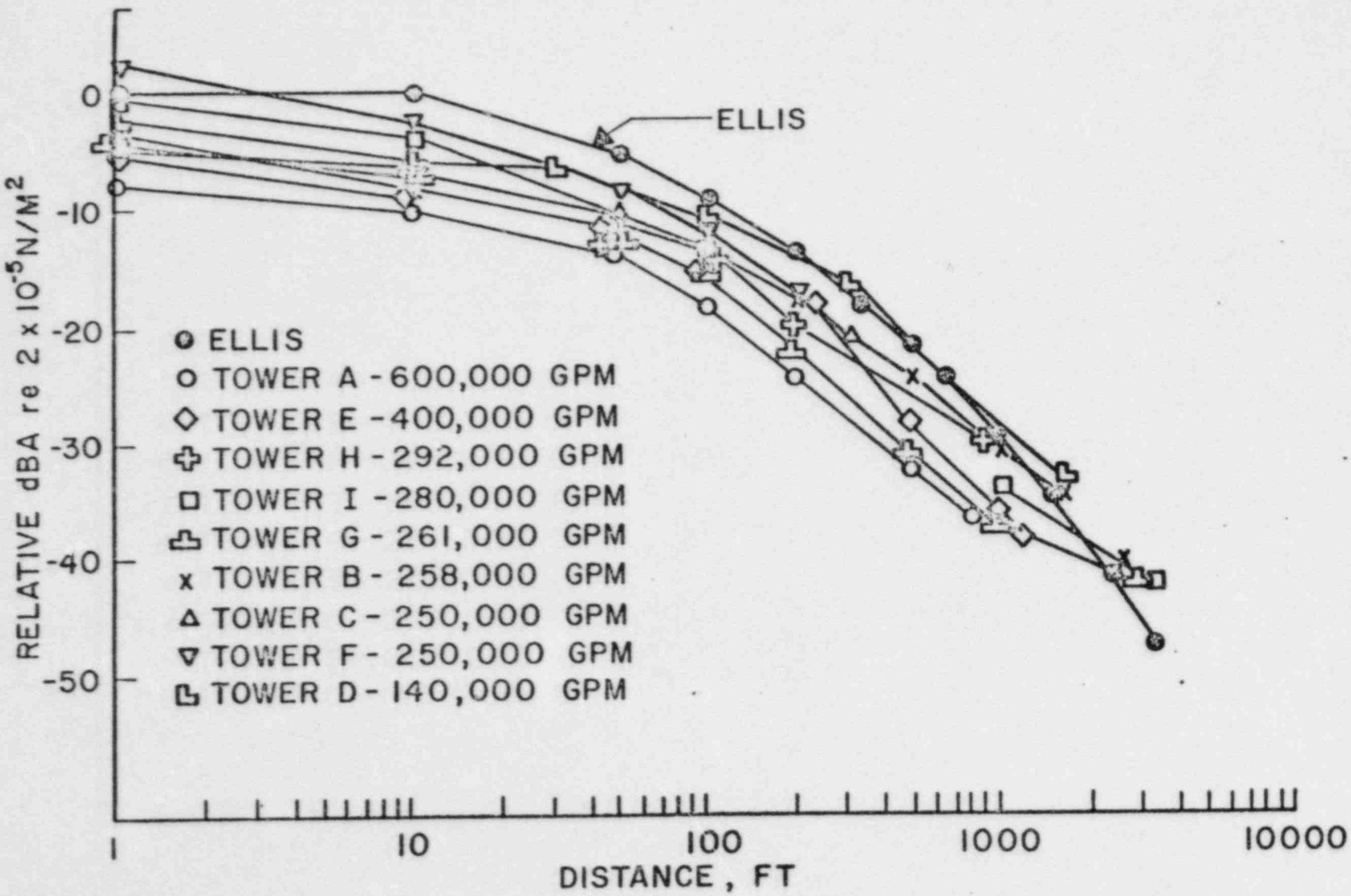
NATURAL & MECHANICAL DRAFT COOLING TOWERS SOUND LEVEL ENVELOPES



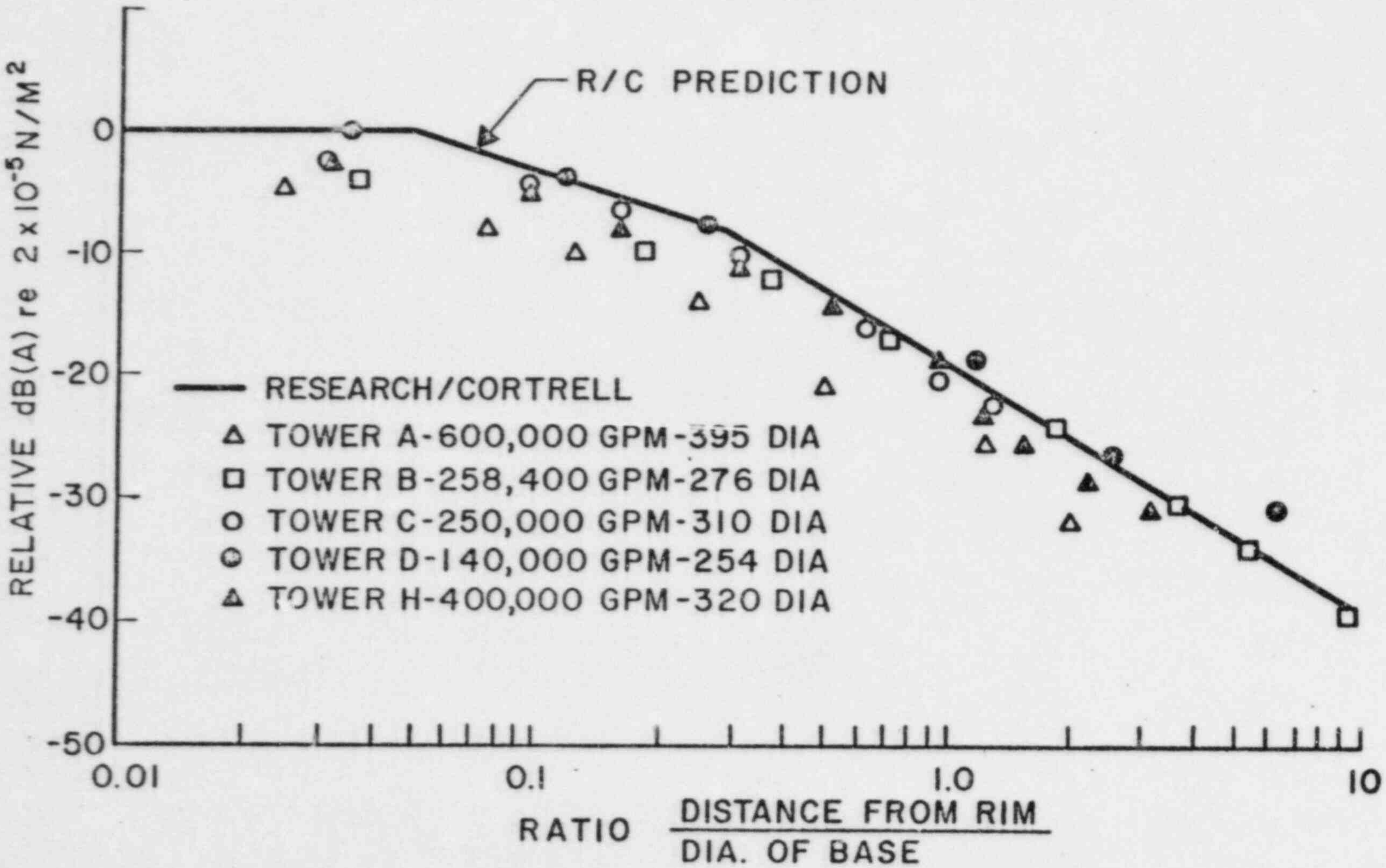
74-2694

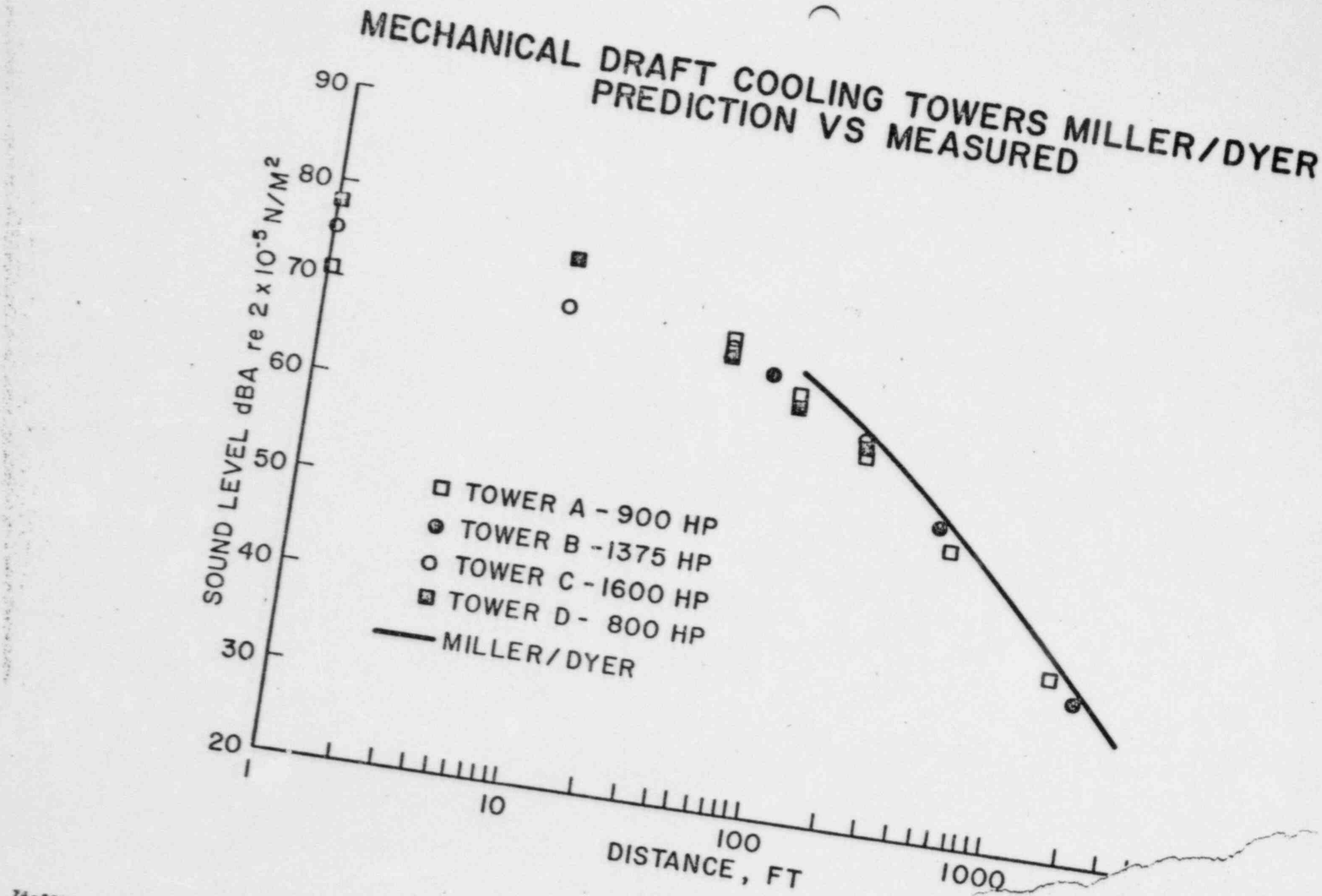
NATURAL DRAFT COOLING TOWERS
ELLIS PREDICTION VS MEASURED



-2696

NATURAL DRAFT COOLING TOWERS
PREDICTION VS MEASURED





MECHANICAL DRAFT COOLING TOWERS MILLER/DYER
PREDICTION VS MEASURED
SOUND LEVEL dBA re 2 x 10^-5 N/M^2
90
80
70
60
50
40
30
20
TOWER A - 900 HP
TOWER B - 1375 HP
TOWER C - 1600 HP
TOWER D - 800 HP
MILLER/DYER
1
10
100
1000
DISTANCE, FT
74-2899

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2. Dyer, I., and Miller, L.N. "Cooling Tower Noise," Noise Control, pp 180-183, May, 1959

3. Research-Cottrell, "Estimation of Noise from Natural Draft Cooling Towers, Counterflow with Film Packing, undated. Research-Cottrell, Hamon Cooling Tower Division Box 750, Bound Brook, New Jersey

4. Aerospace Recommended Practice, ARP866, "Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity for Use in Evaluating Aircraft Flyover Noise." Aug. 31, 1964, Society of Automotive Engineers, 485 Lexington Ave., New York, N. Y.

4/74

Noise Control of Power Plant Cooling Towers. A Study of the Size of Buffer Zone Required to Meet Various Noise Criteria.

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Environmental Division
Project No. 4896-00

INTRODUCTION AND SUMMARY

The purpose of this study was to investigate the size of buffer zone required around power plant cooling towers to meet various noise criteria. Measured field noise data was used as the basis of the analyses and, using certain assumptions, these data were applied to correlate the capacity of the power plant with the area of land necessary to meet various noise criteria for both mechanical (standard) draft and natural draft cooling towers. This correlation is derived in terms of the "specific noise control area" (i.e., the required land area per unit plant capacity, sq. ft. per megawatt). It was found that the specific noise control area was very nearly independent of the plant capacity for both mechanical and natural draft towers, depending only on the A-weighted noise level (dBA) criteria required to be met.

The most important assumptions made in the analyses are as follows:

(1) The noise levels in dBA for natural draft towers vary directly with $[10 \log_{10} (GPM)]$ and with $[10 \log_{10} (HP)]$ for mechanical draft towers. GPM=water flow to the tower and HP=total cooling tower fan horsepower.

(2) The measured data was extrapolated beyond 2000-3000 feet omitting additional acoustic energy loss due to atmospheric absorption, as a conservative estimate.

Using these assumptions, Figure 11 illustrates the relationship between the noise criteria to be met and the specific noise control area as required around either a mechanical or natural draft tower in ft^2/megawatt. This relationship is independent of the megawatt rating of the plant. The range of values indicated in the figure takes into account the fact that the size of tower would vary depending upon, among other things, the ambient design conditions. Since the A-weighted (dBA) noise level is assumed to depend only upon the water flow quantity for a natural draft tower and on the fan horsepower for a mechanical tower, the same megawatt-rated plant could have towers with different noise levels. The range shown in Figure 11 (and in other pertinent figures in this report) covers the appropriate ranges expected for plants throughout the United States.

EXISTING AND PROPOSED NOISE REGULATIONS AND RECOMMENDATIONS

In order to relate cooling tower noise to the size of buffer zone required for noise control, it is necessary to compare the expected tower noise levels with an objective noise criteria. Table 1 illustrates a (non-exhaustive) list of the noise/limits either existing or in the proposal stage throughout the United States. It is felt that the most significant limits in the table are those established by the Federal Environmental Protection Agency. This is an official Agency recommendation (not a regulation) which suggests limiting environmental noise levels to an equivalent A-weighted value of 49 dBA for constant noise sources, as power plant cooling towers would be expected to be. This recommendation is intended to be a guideline for states, counties, municipalities, etc. in establishing enforceable noise limits. It should be anticipated in power plant design that these recommendations will be followed closely in future noise limit regulations.

From Table 1, it is apparent that there is a very wide spread of dBA noise criteria which could be applicable to power plants depending on their specific location. For those limits indicated in the table, this ranges from 40 dBA-65 dBA. This wide range would result in a correspondingly wide range for the size of buffer zone required for noise control of cooling towers. This report, for completeness, includes results covering the entire dBA noise level limit range given in Table 1.

EXPECTED POWER PLANT COOLING TOWER NOISE LEVELS (dBA)

Figures 1 and 2 show, respectively, dBA noise levels measured as a function of distance for mechanical and natural draft cooling towers.(1) The assumption was made in the analyses of this report that the noise levels of mechanical draft towers depended only on the fan horsepower according to $[10 \log_{10} (HP)]$ and noise levels of natural draft towers depended only on the cooling water flow to the tower according to $[10 \log_{10} (GPM)]$. This means, for example, that doubling the horsepower HP (mechanical) or the water flow GPM (natural) would cause the tower noise to increase by 3dBA. This assumption has been suitably verified for mechanical towers but there is some question as to the validity for natural draft towers. It is felt that the assumption of this noise level variation with tower size is desirable for an estimate of the problem at hand (size of buffer zone).

(1) These data were obtained by Consolidated Edison of New York and by Stone & Webster of Boston--the information was presented at the 87th Meeting of the Acoustical Society of America in New York City, April 1974.

Using the above assumption, the solid curves in Figures 1 and 2 show, respectively, the predicted dBA noise levels as a function of distance from a 1600 horsepower mechanical draft tower (HP = 1600) and a 600,000 GPM natural draft tower based on the available measured data. Note that in Figure 2, for natural draft towers, there does not appear to be an apparent consistent variation with cooling water flow quantity to the tower. However, if the assumed variation does indeed occur in the real sense, the flow range covered, from about 140,000 GPM to 600,000 GPM, would represent a $10 \log_{10} (600000/140000) = 6$ dBA difference in noise level from the "quietest" to the "noisiest" tower. It is felt that the small number of towers measured, along with the relatively small spread of expected noise levels, does not conclusively determine whether the noise level variation with water flow does or does not occur in the real sense. However, as mentioned above, the assumption is made in this report that this variation does occur.

From the solid curves in Figures 1 and 2, it is then possible to predict the noise level versus distance for any power plant cooling tower by using these "baseline" curves and raising or lowering them the number of decibels (A-weighted) corresponding to $[10 \log_{10}(HP/1600)]$ for a mechanical draft tower and by $[10 \log_{10} (GPM/600,000)]$ for a natural draft tower;

where HP is the total fan horsepower for the mechanical tower of interest and GPM is the cooling water flow to the natural draft tower of interest.

RANGES OF TOWER NOISE LEVELS EXPECTED THROUGHOUT THE U.S.A.

The ultimate goal here is predict the size of buffer zone required for power plant noise control of cooling towers on the basis of a "specific noise control area"; i.e., the amount of land needed per megawatt of plant capacity. We have, from above, the capability of prediction for noise levels based on either the horsepower (mechanical) or the cooling water flow (natural) related to the cooling tower. However, depending on specific design conditions, the same megawatt capacity plant may have different fan horsepowers or cooling water flow rates. The variation in these quantities is discussed in this section.

Figures 3 and 4 show, respectively, the relationship between plant capacity and tower horsepower (mechanical) and cooling water flow rates (natural) for several existing power plant installations throughout the U.S.A. It is seen from the figures that the horsepower could vary between HP = 3.8 (Mw) and HP = 9.2 (Mw) for mechanical draft towers and the cooling water flow rates could vary between GPM = 300.0 (Mw) and GPM ≐ 588.2 (Mw) for natural draft towers for these several plants. Using the assumed variation in noise levels discussed in the above section, the range of tower noise levels expected could then vary from the "baseline" curves in Figures 1 and 2 by $[10 \log_{10}(3.8Mw/1600)]$ -to- $[10 \log_{10}(9.2Mw/1600)]$ for mechanical draft towers and from $[(10 \log_{10}(300.0Mw/600,000)]$ -to- $[(10 \log_{10}(588.2Mw/600,000)]$ for natural draft towers.

REQUIRED DISTANCE FROM COOLING TOWERS TO MEET VARIOUS NOISE CRITERIA

Figures 1 and 2 provide the information to predict the noise levels from both mechanical draft towers (with fan horsepowers of HP=1600) and natural draft towers (with cooling water flow rates of GPM=600,000) and Figures 3 and 4 provide the information to predict the ranges of tower noise levels possible throughout the country for plants of various megawatt capacities. It is then possible to estimate the distance required from the towers in order to meet a specific dBA noise level limit. Figures 5 and 6 illustrate such results for noise levels from 40 dBA to 65 dBA for mechanical and natural draft cooling towers, respectively. The ranges shown for each noise level limit corresponds to the variation in horsepower or water flow possible depending upon the specific design conditions for each plant given its megawatt capacity.

"SPECIFIC NOISE CONTROL AREA" FOR COOLING TOWER NOISE

We now have the capability, from Figures 5 and 6, to estimate the distance from cooling towers at which various noise level limits (dBA) will be achieved. Of primary interest is the area of land per unit plant capacity. This area will, of course, depend not only upon the distance from the tower but also on the area required by the tower itself. Having the size of tower and the distance from it to meet a noise level limit, it is possible to calculate the total area of land required for noise control.

Figures 7 and 8 show, respectively, the length of mechanical towers and the diameter of natural draft towers for several plants of various megawatt capacities. The solid lines in the figures illustrate the assumed variation in tower size as a function of the plant capacity. The spread in the data for natural draft towers in Figure 8 is quite wide--however, since in most cases the total area of land required to meet a noise level limit will be controlled by the distance from the tower this wide spread in data should not result in large relative errors in estimating the total area.

The "specific noise control area" required for mechanical draft towers is assumed to be given by

$$A_s = \frac{(L + 2D)\ (W + 2D)}{Mw},\ ft^2/\text{megawatt}$$

and for natural draft towers by

$$A_s = \frac{\pi(R + D)^2}{Mw},\ ft^2/\text{megawatt}$$

where A_s = specific noise control area required, ft^2/megawatt

L = length of mechanical draft tower (assumed all cells are in-line), ft.

D = distance from nearest surface of the tower, ft.

W = width of mehcanical draft tower cell, assumed 40 ft.

R = radius of round natural draft tower, ft.

Mw = megawatt capacity of power plant where tower is installed.

Based on the above analysis and the distance values from Figures 7 and 8, the "specific noise control area" A_s is shown plotted in Figures 9 and 10 for mechanical and natural draft towers, respectively, for various noise level limits and for plant having different capacities. The analysis indicates, as seen from Figures 9 and 10, that the value of A_s is nearly independent of the plant capacity and depends only on the noise level limit to be achieved. As was pointed out earlier, the recommended limit of 50 dBA (approximately) by the Federal Environmental Protection Agency is felt to be the most significant noise criteria in that future legislation is anticipated to be consistent with this recommendation.

Figure 11 summarizes the ultimate results of this study giving the specific noise control area A_s as a function of the dBA noise level limit to be achieved. The figure was derived from Figures 9 and 10, where the dependence on the plant capacity has been removed; i.e., A_s is nearly independent of the plant capacity in megawatts. From Figure 11, for the 50 dBA noise level limit to be achieved for cooling tower noise, without any other form of noise control being implemented, would require between 14,000-27,000 ft^2/megawatt (or 0.322-0.621 acres/megawatt) for natural draft towers and between 35,000-90,000 ft^2/megawatt (or 0.805-2.07 acres/megawatt) for mechanical draft towers.

April, 1974

TABLE 1

LIST OF VARIOUS (EXISTING OR PROPOSED) NOISE REGULATIONS IN TERMS OF THEIR A-WEIGHTED (dBA) EQUIVALENT PERMITTED AT RESIDENTIAL BOUNDARY LINES

Source of Regulation or Recommended Limits	Equivalent dBA Level Daytime	Nighttime
Illinois Pollution Control Board	61	51 (1)
Federal Environmental Protection Agency (2)	49	49
Oregon Department of Environmental Quality	60	55
New York City Zoning Regulations	60	60
New York City Noise Control Code	55 (3)	55 (3)
New York State Dept. of Environmental Conservation	65	45 (4)
Dept. of Housing and Urban Development (HUD)	55 (5)	55 (5)
New Jersey Dept. of Environmental Protection	65	50 (6)
Washington, D. C.	55	50 (7)
St. Louis County (Missouri)	55	50
Montgomery, Alabama	55	55
North Carolina	60	55
San Diego, Calif. Noise Ordinance	45	40
Lakewood, Colorado	55	50
Boston, Mass.	60	50
Baltimore, Maryland	58	53
Dallas, Texas	56	49
Miami, Florida	55	52
Los Angeles, California	55	45
San Francisco, California	55	50
Dayton, Ohio	56	56

TABLE 1 (Continued)

Source of Regulation or Recommended Limits	Equivalent dBA Level Daytime	Nighttime
Chicago, Illinois	55	55
Columbus, Ohio	52	52
Beverly Hills, California	40	40
Hemet, California	50	50
Fairlawn, New Jersey	55	--
Peoria, Illinois	53	--
Annaheim, California	60	60
Minneapolis, Minnesota	55	55
Tucson, Arizona	55	55

(1) Does not apply to "existing" sources -- if legislation forces C.T. installation, would not be considered a "new" source and this number would not apply.

(2) Recommended limit value is L_{dn} = 55 dBA; the relationship between L_{dn} and a constant dBA noise level L is $L_{dn} = L+6$ dBA.

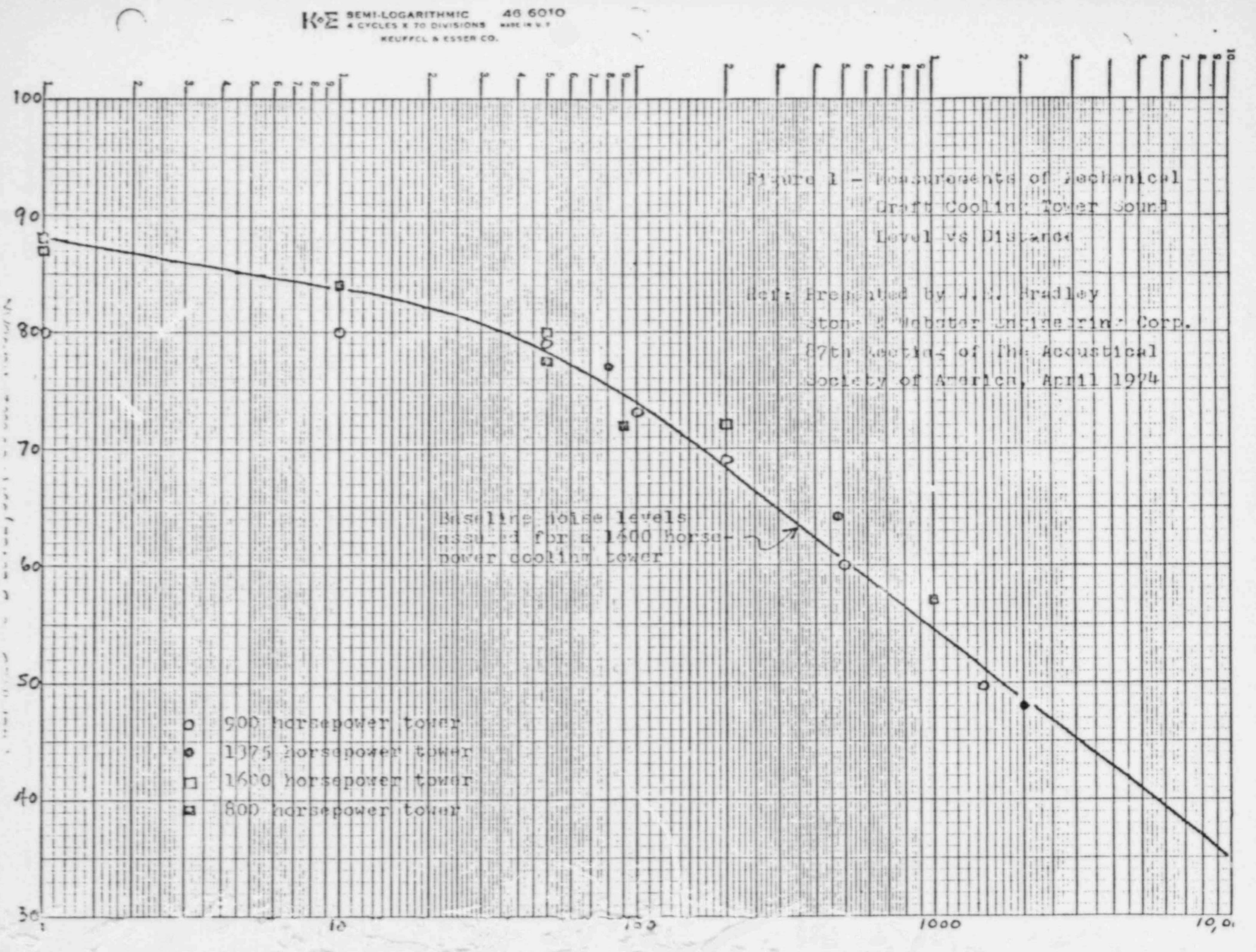
(3) Code limits interior noise level to 45 dBA; a 10 dBA noise reduction for open windows is assumed.

(4) Does not apply to "existing" sources (installation initiated prior to July 1, 1974) or to site modifications made prior to January 1, 1975.

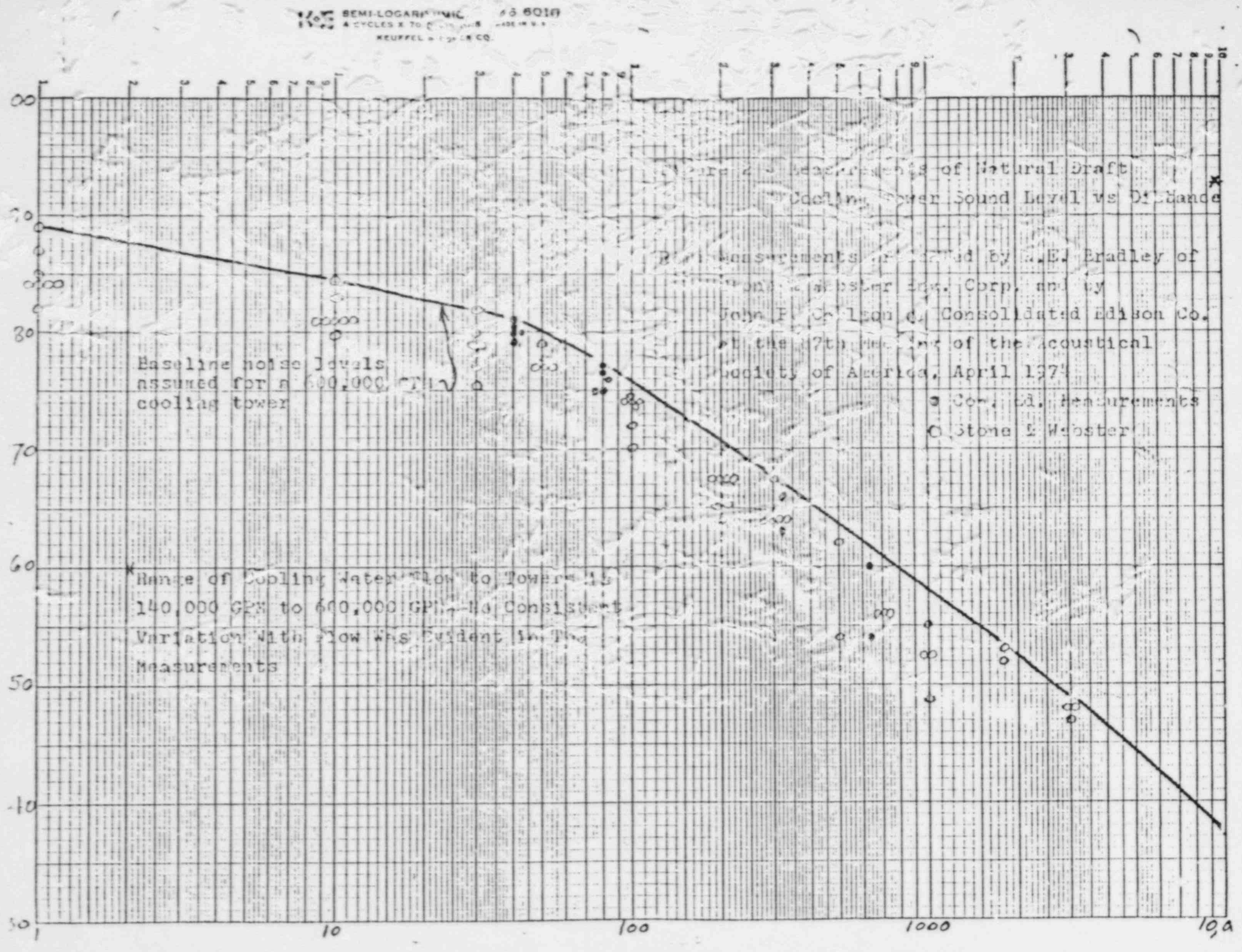
(5) This is taken in the mid-range of the 45-65 dBA "normally acceptable" HUD values.

(6) This value will be applicable after January 1, 1976 -- the value of 55 dBA will apply until then.

(7) The limits are specified in dBC values -- the table values are the approximate corresponding dBA values.



K&E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS 46 6010
KEUFFEL & ESSER CO.
Figure 1 - Measurements of Mechanical Draft Cooling Tower Sound Level vs Distance
Ref: Presented by J. L. Bradley Stone & Webster Engineering Corp. 87th Meeting of The Acoustical Society of America, April 1974
Baseline noise levels assumed for a 1600 horsepower cooling tower
900 horsepower tower
1375 horsepower tower
1600 horsepower tower
800 horsepower tower
100
90
80
70
60
50
40
30
1
10
100
1000
10,000


SEMI-LOGARITHMIC 46 6010
KEUFFEL & ESSER CO.
Measurements of Natural Draft
Cooling Tower Sound Level vs
Measurements ... by ... Bradley of
Corp. and by
Consolidated Edison Co.
of the Acoustical
Society of America, April 197
Con. Ed. Measurements
Stone & Webster
Baseline noise levels
assumed for a 600,000
cooling tower
Range of Cooling Water Flow to Tower is
140,000 GPM to 600,000 GPM--No Consistent
Variation With Flow Was Evident in The
Measurements
10
100
1000

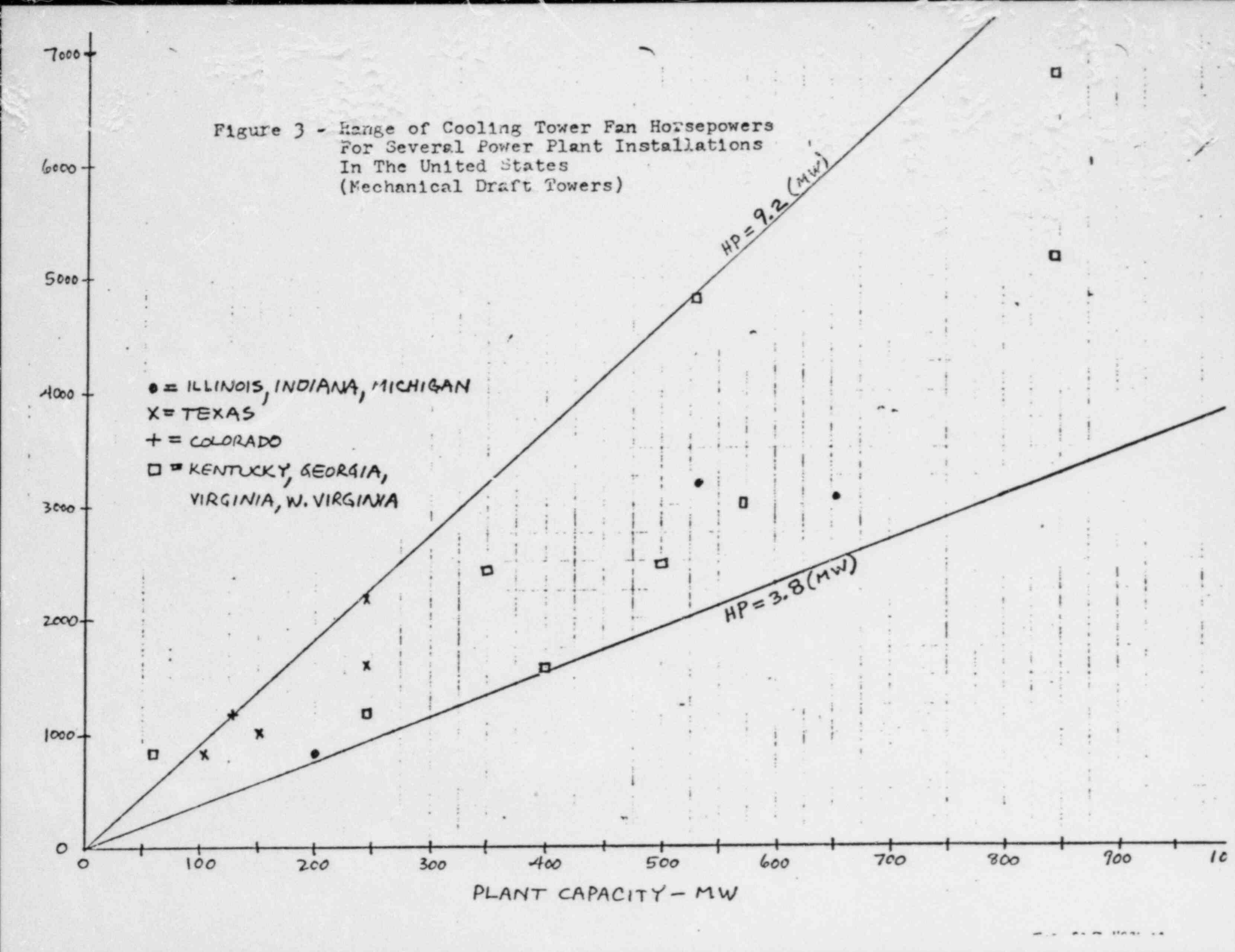


Figure 3 - Range of Cooling Tower Fan Horsepowers
For Several Power Plant Installations
In The United States
(Mechanical Draft Towers)
HP = 9.2 (MW)
HP = 3.8 (MW)
● = ILLINOIS, INDIANA, MICHIGAN
X = TEXAS
+ = COLORADO
□ = KENTUCKY, GEORGIA,
VIRGINIA, W. VIRGINIA
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
700
800
900
PLANT CAPACITY – MW

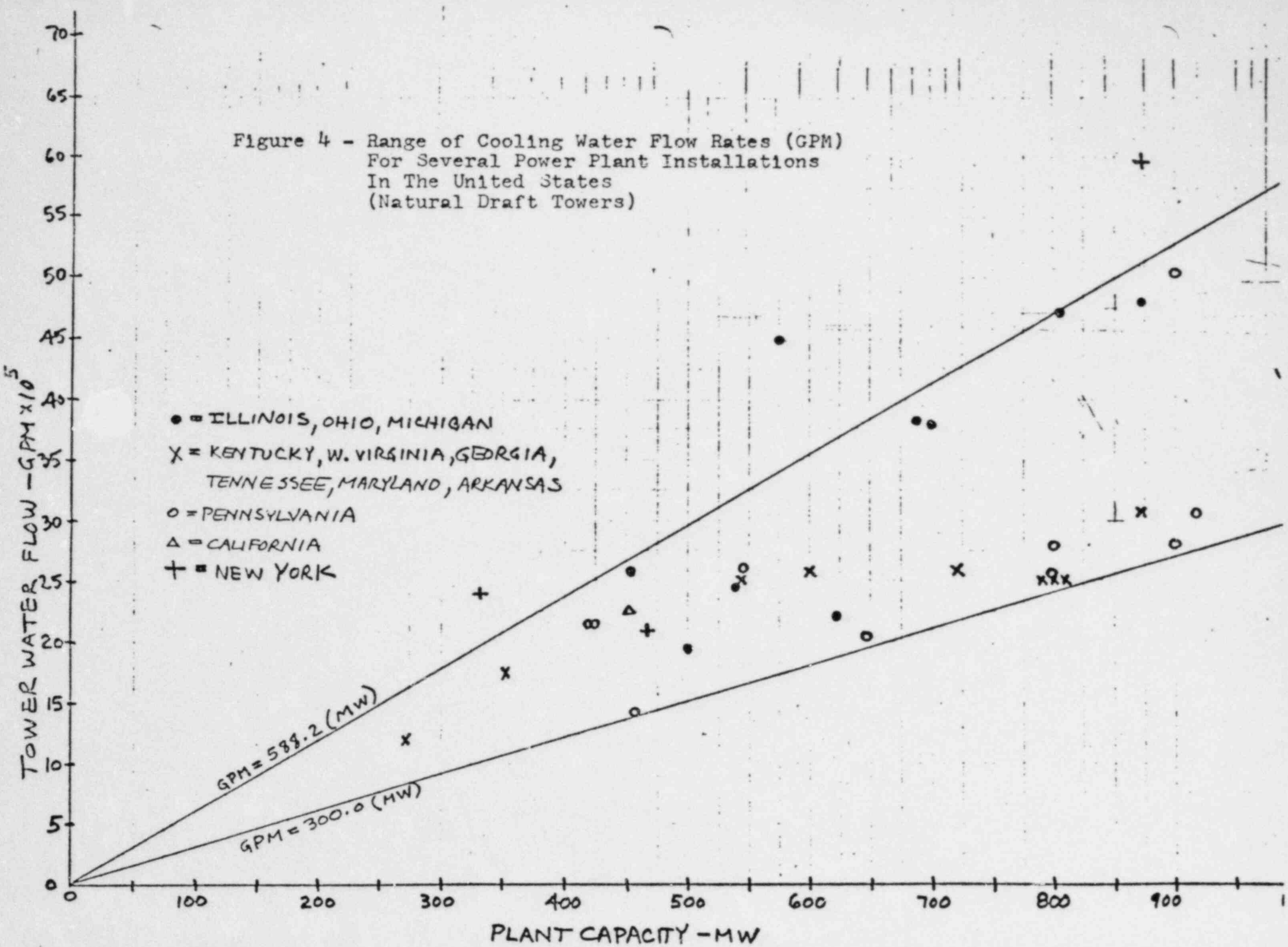
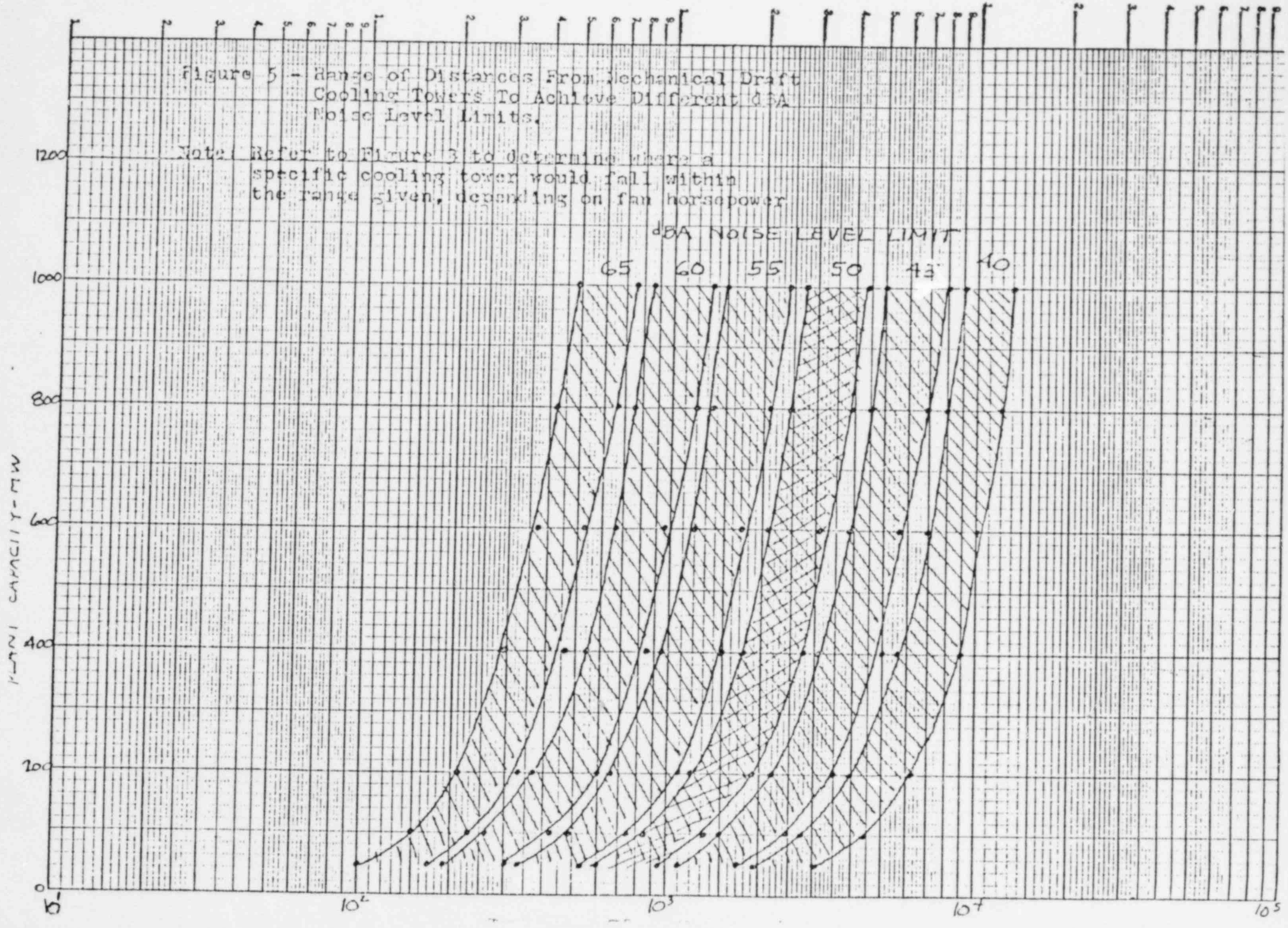


Figure 4 - Range of Cooling Water Flow Rates (GPM) For Several Power Plant Installations In The United States (Natural Draft Towers)

K+E SEMI-LOGARITHMIC 46 6010
4 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Figure 5 - Range of Distances From Mechanical Draft Cooling Towers To Achieve Different dBA Noise Level Limits.

Note: Refer to Figure 3 to determine where a specific cooling tower would fall within the range given, depending on fan horsepower



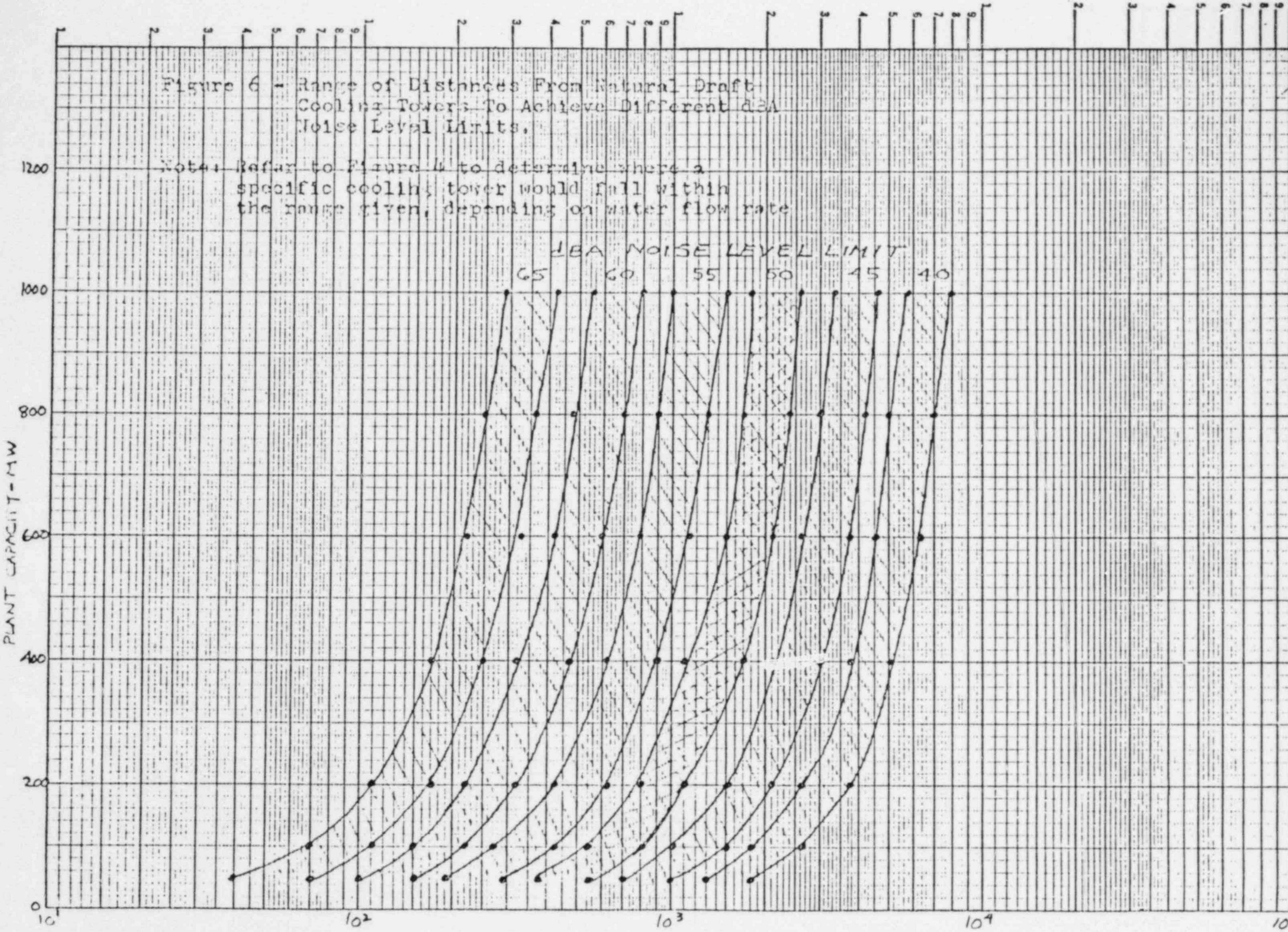


Figure 6 - Range of Distances From Natural Draft Cooling Towers To Achieve Different dBA Noise Level Limits.

Note: Refer to Figure 4 to determine where a specific cooling tower would fall within the range given, depending on water flow rate

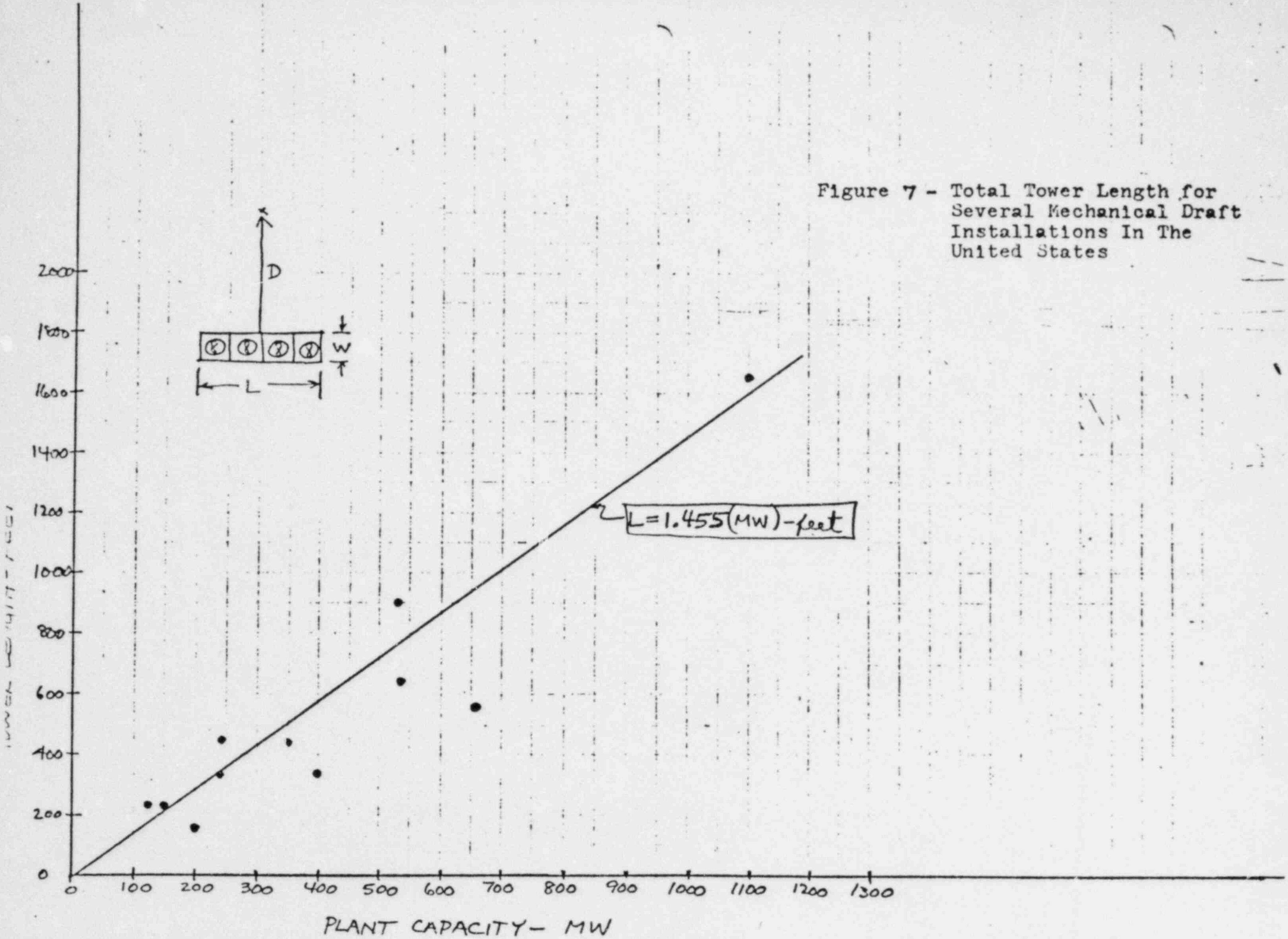


Figure 7 - Total Tower Length for Several Mechanical Draft Installations In The United States

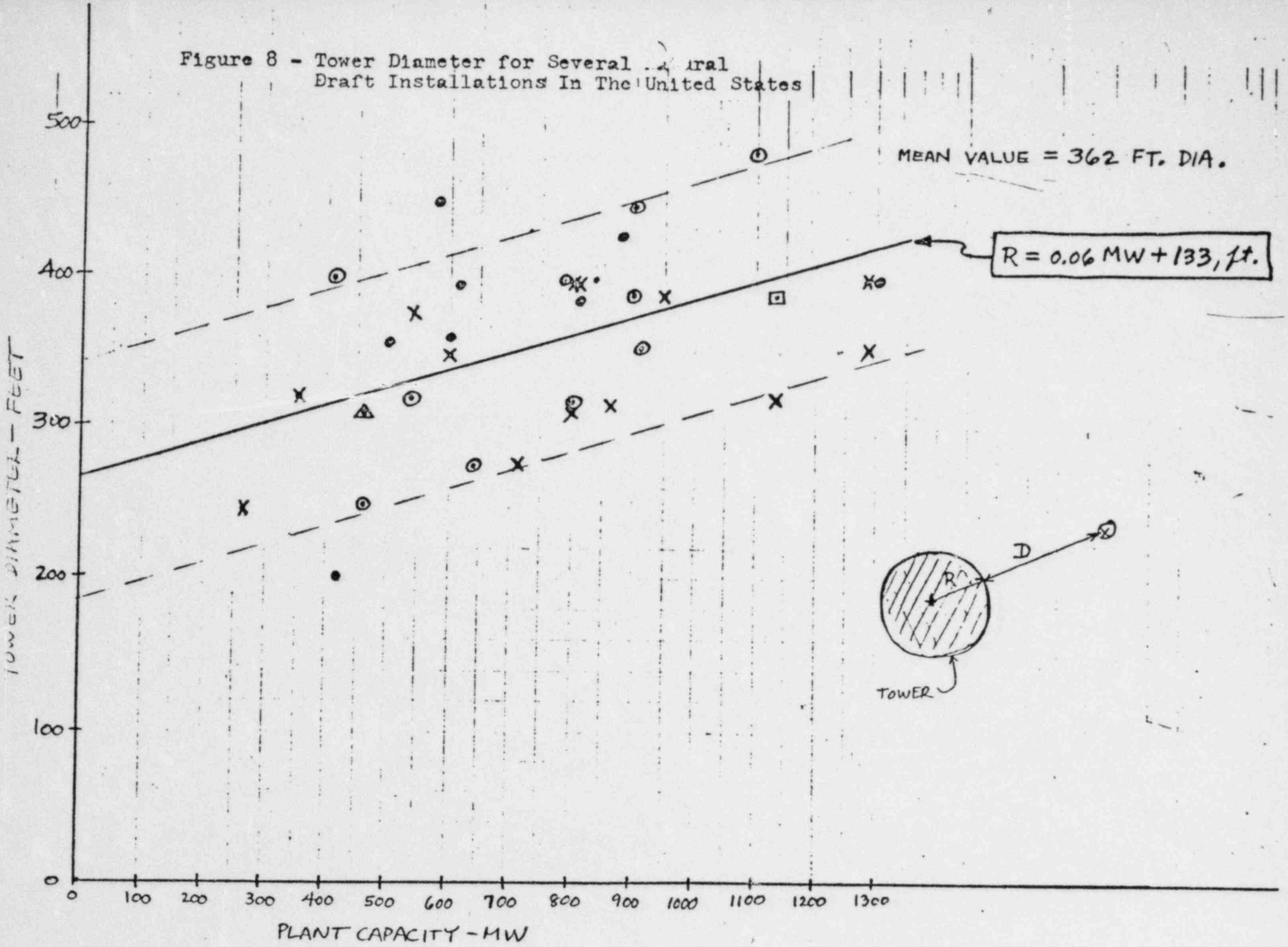


Figure 8 - Tower Diameter for Several Natural Draft Installations In The United States

K&E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS 46 6010 MADE IN U.S.A. KEUFFEL & ESSER CO.

Figure 9 - "Specific Noise Control Area" Required For Mechanical Draft Cooling Towers To Achieve Different dBA Noise Level Limits

Note: Refer to Figure 3 to determine where a specific cooling tower would fall within the range given, depending on fan horsepower

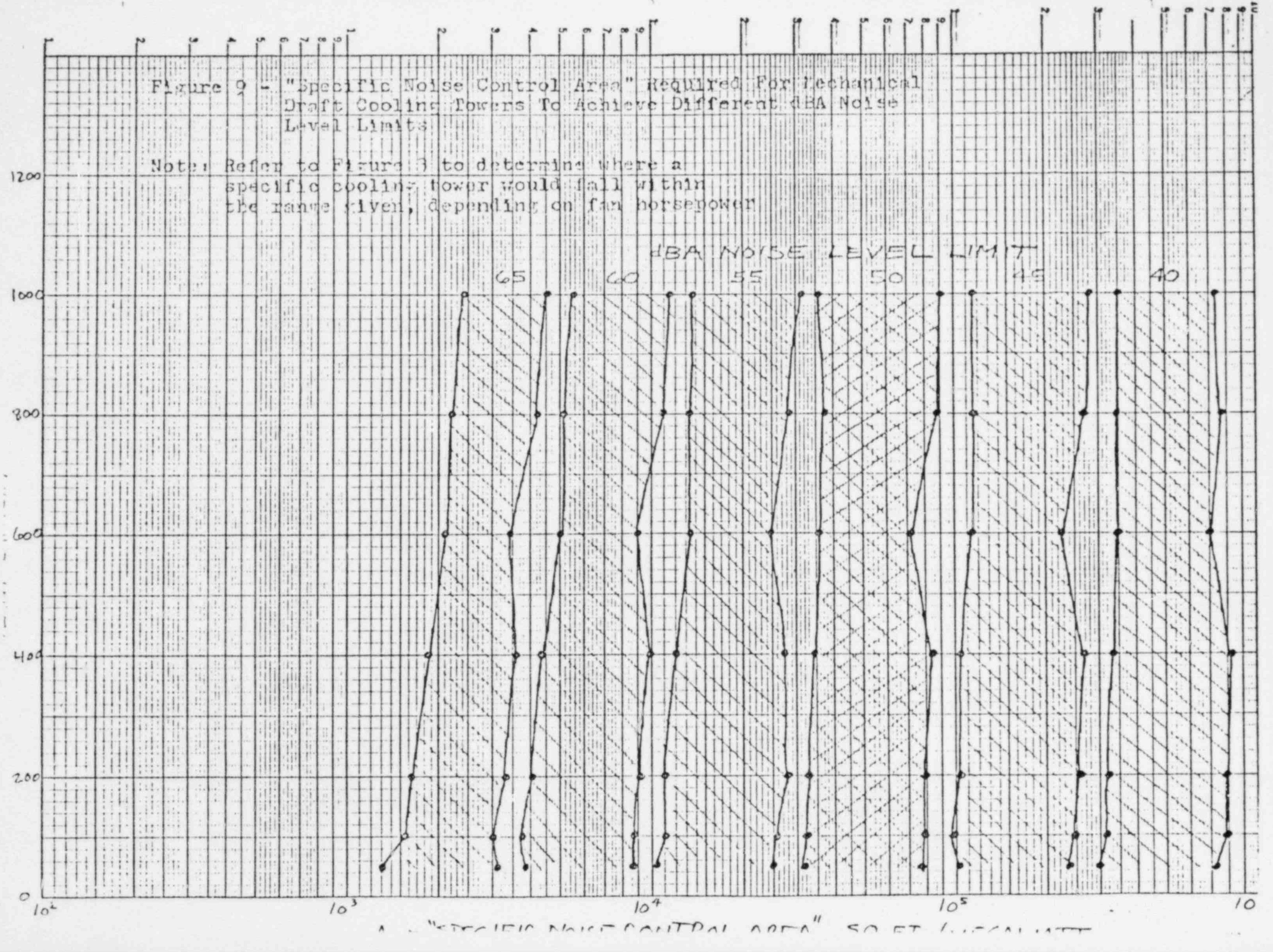
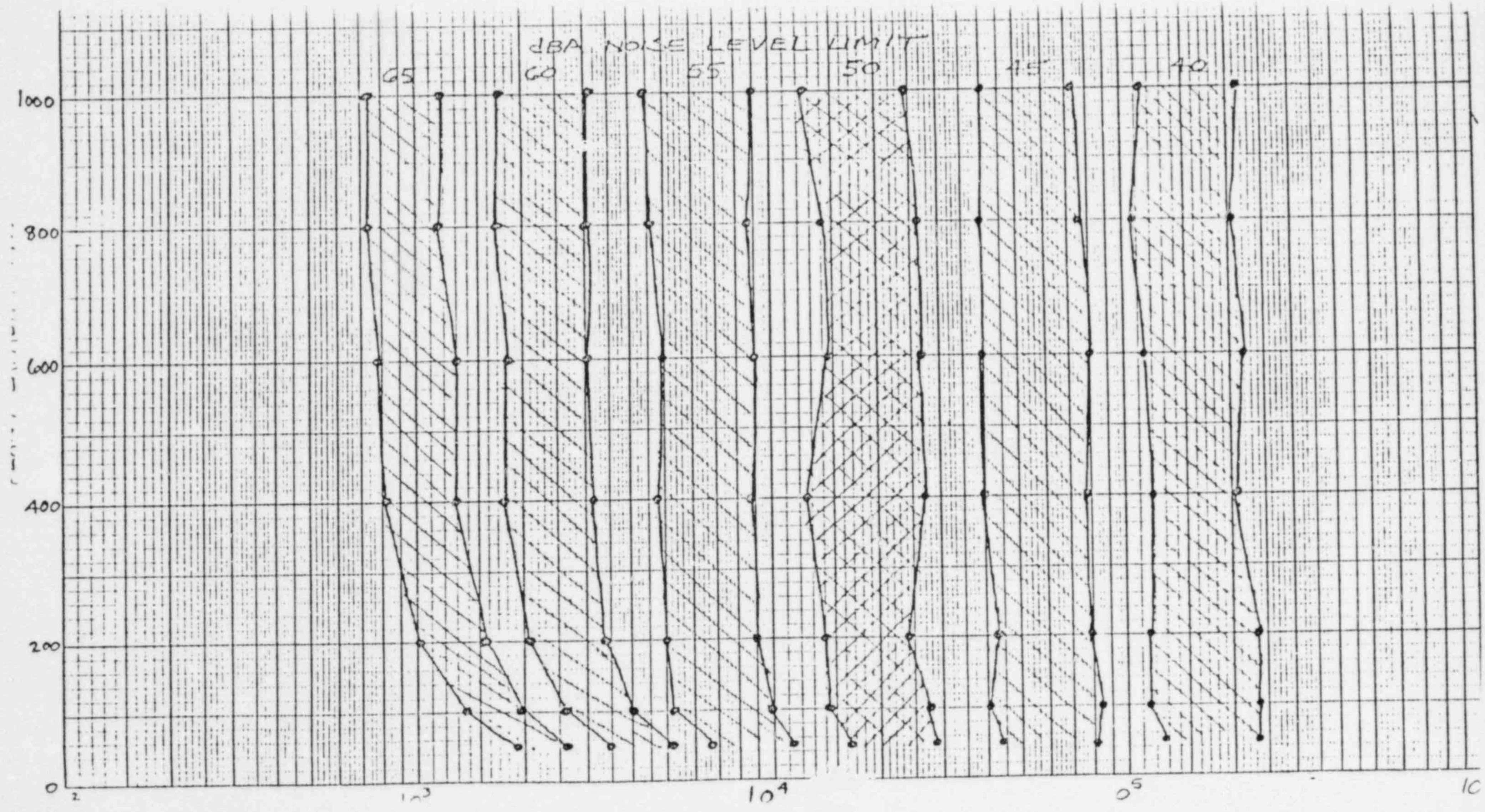
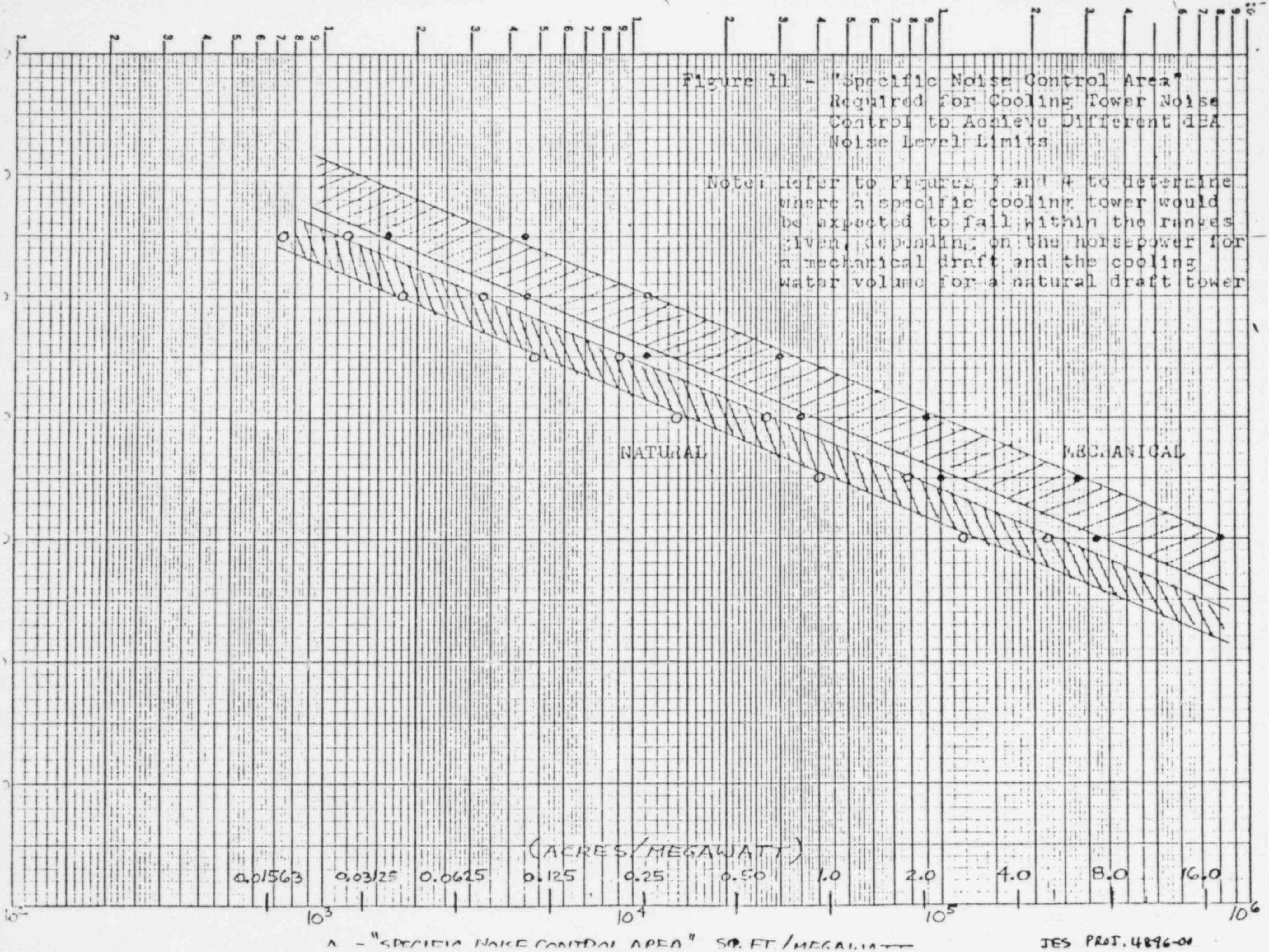


Figure 10 - "Specific Noise Control Area" Required for Natural Draft Cooling Towers To Achieve Different dBA Noise Level Limits

Note: Refer to Figure 4 to determine where a ... cooling tower would fall within





JES PROJ. 4896-01

COOLING TOWER NOISE EMISSION CONSIDERATIONS

A. Discussion

The environmental impact of noise emissions from cooling towers can best be determined by (1) determining the sound level that the cooling tower in association with a particular plant will cause at a neighboring property line, and (2) comparing that sound level with the most restrictive noise standard permitted by law.

Cooling tower noise emissions will vary from installation to installation depending upon such factors as type (mechanical or natural draft), size, water flow rate, horsepower, orientation, topography and meteorology. For a 600 to 800 MW power plant we have compared, figure 1, a typical range of cooling tower sound emissions with distance from the tower.

The federal Noise Control Act of 1972, which is administered by EPA, provides for the states or local political subdivisions to control and enforce environmental noise standards. Figure 2 illustrates typical current permissible boundary noise levels. In general, the more restrictive nightime community noise regulations will limit utility operations, since equipment must operate continually. This statement considers the impact of cooling tower noise emissions at night, and assumes that permissible property line noise levels will be less than 50 dB(A), see figure 2.

With these limiting conditions established, Table I was constructed to illustrate the physical distance required from the cooling tower to residential areas at which the sound level would be reduced to below 50 dB(A). Since a cooling tower is only part of a larger generating station complex, Table I illustrates several different practical conditions. The size of the acoustical buffer zone required to attenuate cooling tower noise emissions is a severe restriction in planning and siting new power plants (condition II of Table I), and may be prohibitive when considering retrofit requirements of existing power plants (condition III a and III b of Table I). A discussion of the reasons behind the calculations to construct Table I is presented as an enclosure.

The estimate of the size of the acoustical buffer zone supposes that the cooling tower and the generating facility noise emissions would impose an increase in the community noise level that would be acceptable to the community. Regulations to further decrease sound emissions to below those considered in this statement would necessitate increasing the amount of real estate beyond that shown in Table I to further attenuate the sound.

B. Conclusions

New Facilities: New facilities can be planned to have a sufficiently large buffer zone, 1/2 to 1 mile in radius in order to attenuate plant and cooling tower noise.

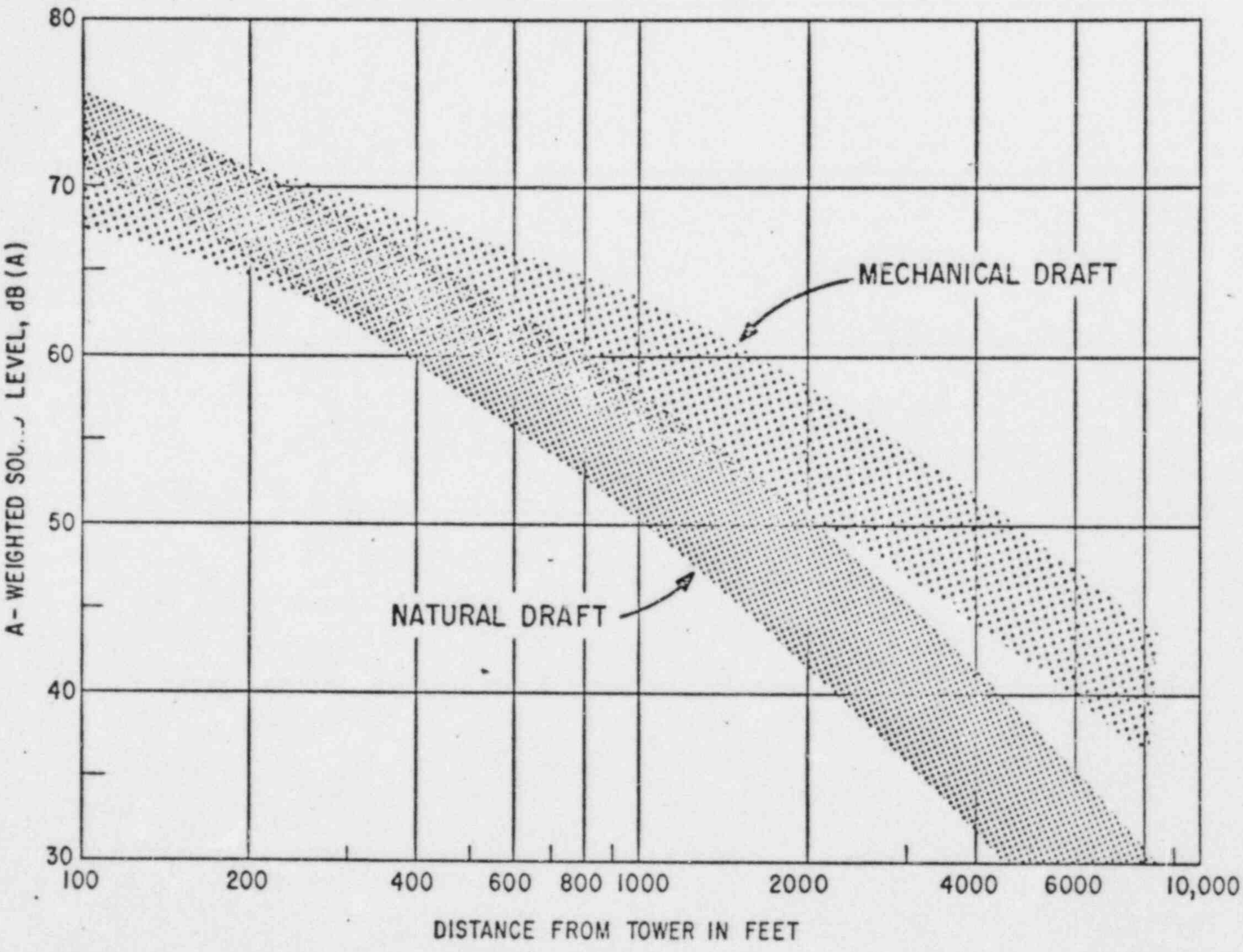
Existing Facilities: At existing facilities, acoustical buffer zones of 0.6 to 2 miles in radius may be required to comply with local regulations.

C. Recommendations

It is recommended, as in the case of "Drift", that EPA consider granting exemptions from the Thermal Effluent Limitations when a utility does not own sufficient real estate to provide an acoustical buffer zone to attenuate cooling tower sound emissions to an acceptable level and when no other practical method exists for attenuating the sound. This recommendation obviously involves considerations of acquisition of additional real estate, and hence of additional costs. Effluent limitation guidelines which do not consider the real estate implications (and the costs of alternatives) required for abatement of environmental noise emissions from cooling towers would not be complete or workable.

FIGURE 1

TYPICAL RANGE OF COOLING TOWER NOISE
EMISSIONS FOR 600/800 MW PLANT
WITHOUT EFFECTS OF TOPOGRAPHY OR METEOROLOGY



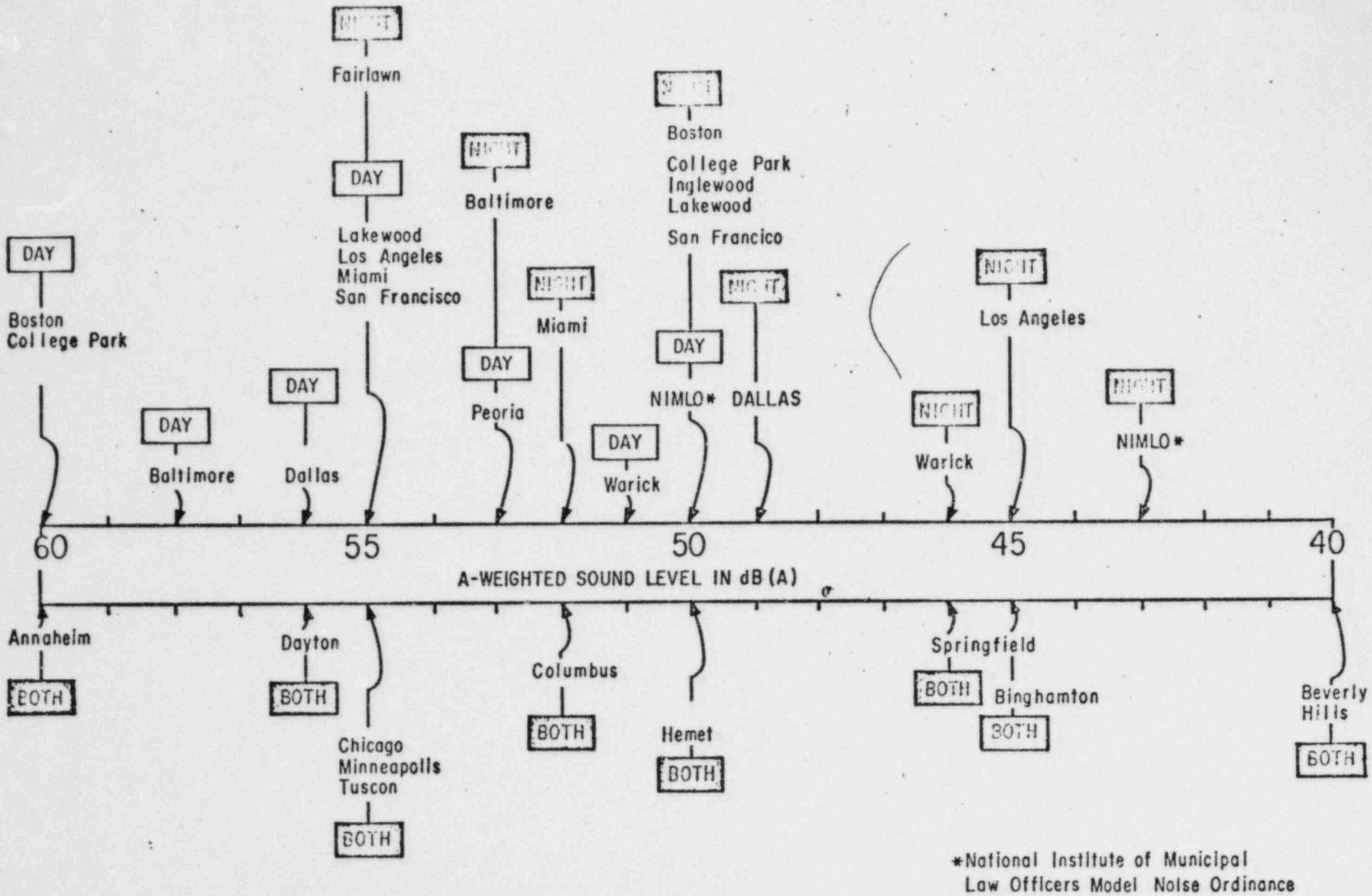


FIGURE 2. FIXED SOURCE NOISE LEVELS ALLOWABLE AT RESIDENTIAL BOUNDARIES

SOURCE : ENVIRONMENTAL NOISE WORKSHOP, REGION II, E.P.A., JUNE 1973

Tabl

Estimated Acoustical Buffer Zones for Cooling Tower Installations
for 600 to 800 MW Generating Plant

	Type of Installation	Nominal Distance* to Residential Area to Achieve less than 50 dB(A) Sound Level	
		Natural Draft	Induced Draft
I	Cooling Tower	1,800 feet	4,000 feet
II	Cooling Tower plus New Generating Station	2,400 feet	5,000 feet
III a	Cooling Tower Retrofitted to Existing Station with 1 dB(A) increase in Community Sound Level	3,000 feet	8,000 feet
IIIb	Cooling Tower Retrofitted to Existing Station with no increase in Community Sound Level	3,500 feet	10,000 feet

* distances will vary depending upon cooling tower water flow rate, horsepower, physical size, topography and meteorology.

ATTACHMENT

Cooling tower noise emissions are presented and evaluated in terms of the A-weighted sound level for numerous reasons: (a) the sound emitted in continuous and the frequency spectra is broad band, (b) this method provides a single value that can be easily compared to sound from other sources or existing data in the literature, and (c) the A-weighted sound level is the parameter being used by various government agencies to regulate noise emissions.

Based upon existing local noise requirements and recomended EPA guidelines, permissible power plant noise emission requirements in suburban rural areas are often required to be less than 50 dB(A), and in urban areas where vehicular traffic increases the community ambient noise level, permissible noise levels would generally range from 50 dB(A) to 55 dB(A).

At a power plant site, there are numerous sources producing noise other than cooling towers. At a new plant site, compliance with permissible property line sound regulations may be achieved by allocating equal acoustic power emission by the cooling tower and the other mechanical equipment in the generating station. This means that the permissible noise emission level of the cooling tower would be reduced from 45 dB(A) to 50 dB(A) by 3 dB to 42 dB(A) to 47 dB(A).

Determination of the permissible sound contribution of a new cooling tower at an existing plant is significantly more complicated because of the existing relationship of the generating station noise emissions to the local permissible noise requirements. For example, if the noise emissions from an existing generating station complies with the local noise control ordinance, the sound emission level from the new cooling tower would have to be 6 dB(A) below the existing plant noise emission level to have a sound level increase of 1 dB(A) at the residential area, or the cooling tower sound emission level would have to be 9 dB(A) below the existing plants noise emission level if there is to be no increase in existing community noise. The maximum permissible noise emission level from a cooling tower retrofitted in an existing plant in a rural or suburban area could be 39 dB(A) to 44 dB(A) for a 1 dB(A) increase, or 36 dB(A) to 41 dB(A) for no community noise increase.

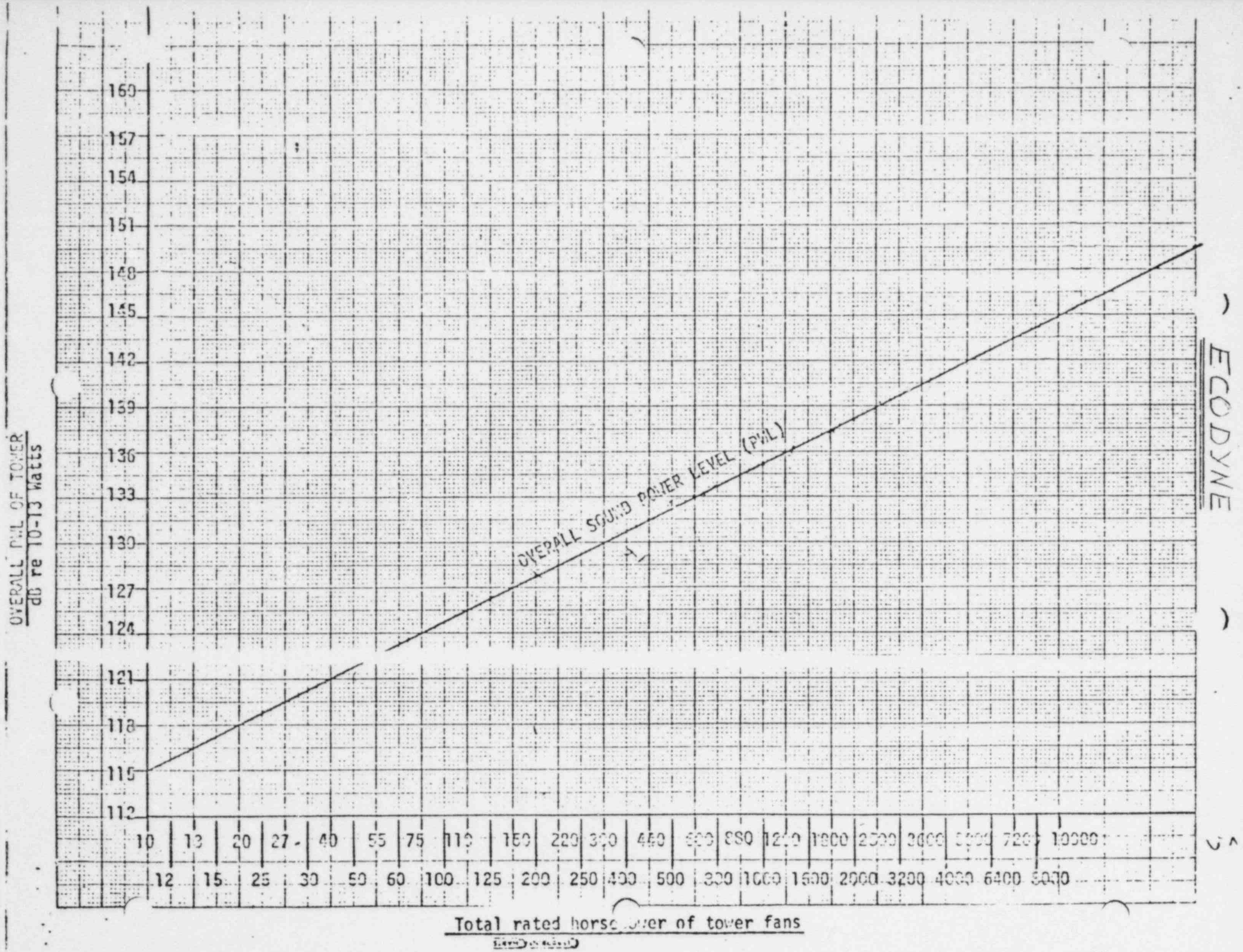

ECODYNE
OVERALL PWL OF TOWER
dB re 10-13 Watts
160
157
154
151
148
145
142
139
136
133
130
127
124
121
118
115
112
OVERALL SOUND POWER LEVEL (PWL)
10
12
15
20
25
30
40
50
55
60
75
100
125
200
250
400
440
500
1000
1600
2000
3200
4000
6400
10000
Total rated horsepower of tower fans

TABLE II

*ATTENUATIONS, Octave Band, Center Band Frequency, cps

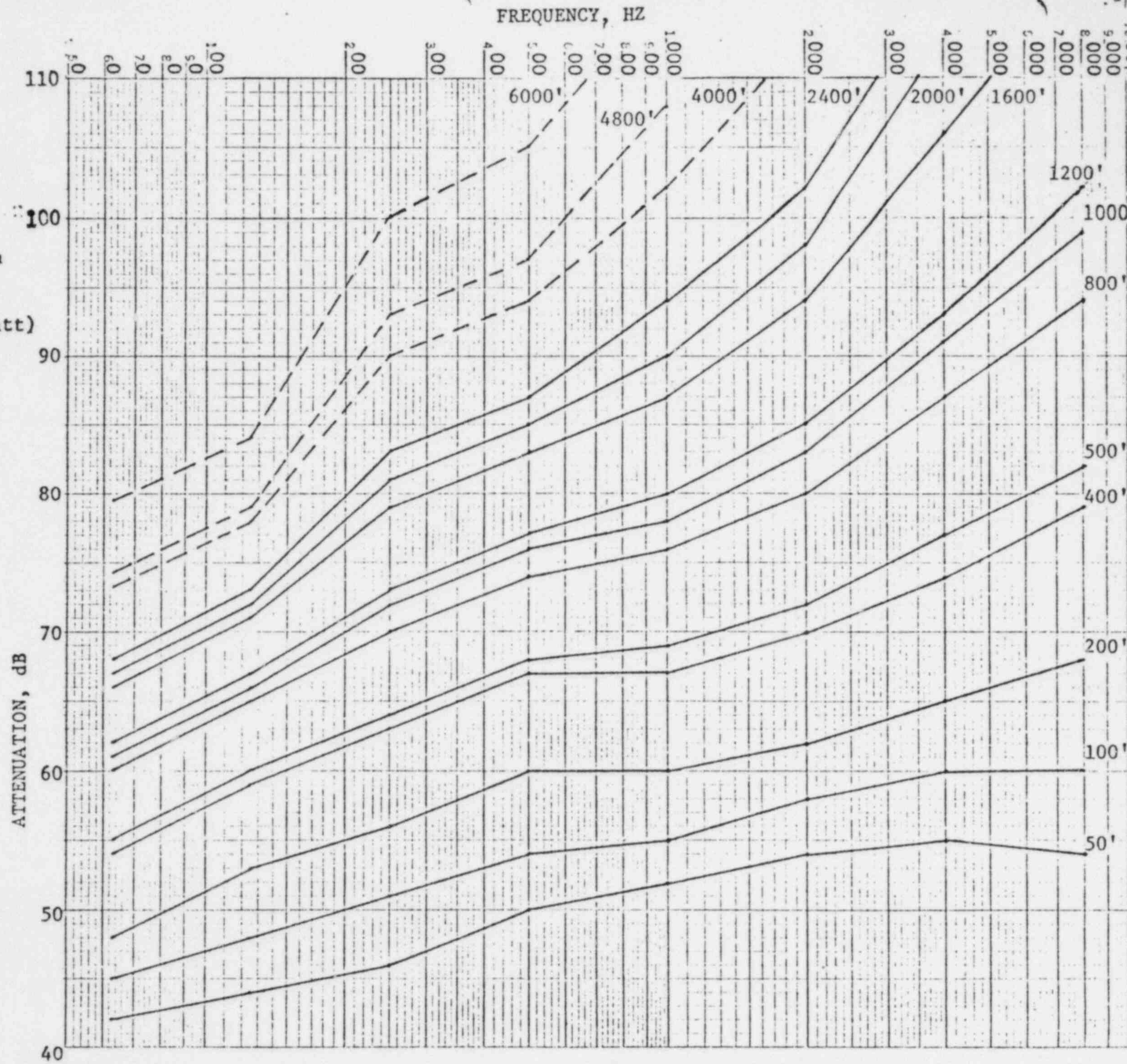
Distance, Ft.	63	125	250	500	1000	2000	4000	8000
50	52	54	56	60	62	64	65	64
100	55	58	61	64	65	68	70	70
200	58	63	66	70	70	72	75	78
400	64	69	73	77	77	80	84	89
500	65	70	74	78	79	82	87	92
800	70	75	80	84	86	90	97	104
1000	71	76	82	86	88	93	101	109
1200	72	77	83	87	90	95	103	112
1600	76	81	89	93	97	104	116	128
2000	77	82	91	95	100	108	123	137
2400	78	83	93	97	104	112	128	144
A-Scale	25	16	9	3	0	-1	-2	-2
**End Wall	0	0	0	7	7	9	9	11

*Attenuation for distance based on measurement location perpendicular to louvre face. The attenuation values assume a tower location with little or no interference from the surroundings. Minimum SPL to be reported is 24 dB.

** If sound measurement location is at an end wall and within 400 ft. of the tower select PWL based on single cell HP and deduct the end wall attenuation values in addition to the attenuation values shown in Table II.

FIGURE 25.

Total attenuations to be subtracted from sound-power level (L_w re 10^{-12} watt) to obtain sound-pressure level at various distances from the source.



NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Company - Plant Bowen
JOB NO: ____ DATE: 9-20-72
OBSERVERS: C. E. Hickman

INSTRUMENTATION

- SLM: TYPE ____ SER. # ____
- TRANSDUCER: TYPE GR1560-P6 SER. # 1950
- ANALYZER: TYPE GR1558-BP SER. # 2279
- CABLE: TYPE ____ LENGTH ____
- CALIBRATOR: TYPE GR1562-A SER. # 3122
- OTHER: ____

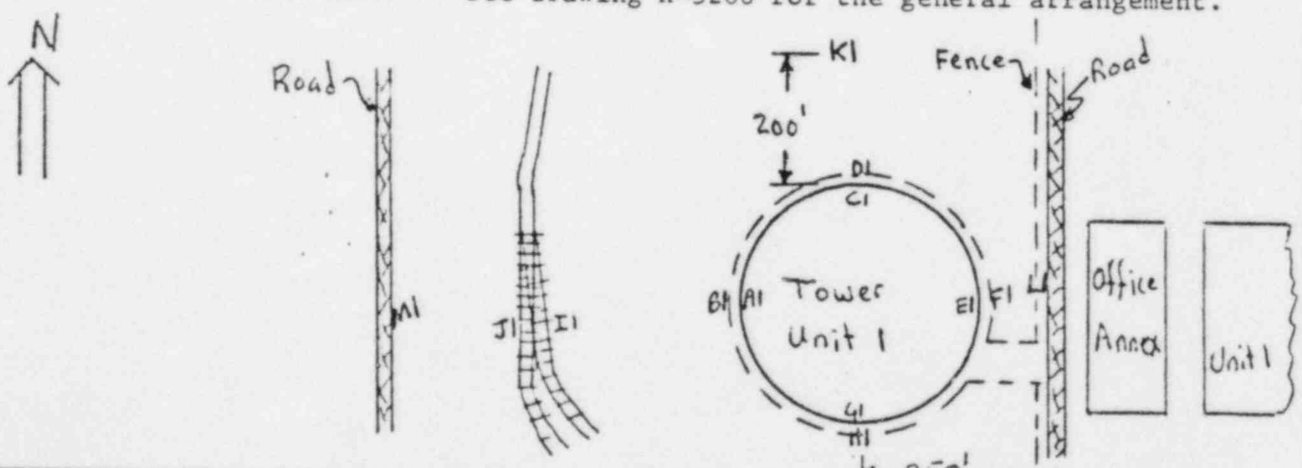
PRIMARY NOISE SOURCE: Unit 1 cooling tower
EQUIP. MAKE & MODEL: Res. Cottrell Natural Draft
CLIENT DESIGNATION: Unit 1
OPERATING CONDITIONS: Unit 1 operating at rated load
Cooling tower is counterflow type

SECONDARY NOISE SOURCE: ____
EQUIP. MAKE & MODEL: ____
CLIENT DESIGNATION: ____
OPERATING CONDITIONS: ____

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
1:25p	OK					

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.								
						31.5	63	125	250	500	1000	2000	4000	8000
1	1:30p	A1	Base of tower	86	89	80	74	72	71	76	79	77	78	82
2		B1	At fence≈15' from base	82	87	79	73	73	68	72	75	74	74	77
3		C1	Base of tower	86	89	80	74	75	72	75	78	77	78	82
4		D1	At fence≈15' from base	83	88	80	73	74	70	73	75	75	76	78
5		E1	Base of tower	87	89	80	82	77	75	78	79	79	79	83
6		F1	At fence≈15' from base	84	87	80	81	76	72	73	76	76	77	78
7		G1	Base of tower	87	89	80	79	74	74	79	79	78	80	83
8		H1	At fence≈15' from base	85	88	80	78	72	69	74	76	76	77	81

DIAGRAM - SHOW MEASURING LOCATIONS: See drawing H-5200 for the general arrangement.



RECOMMENDATIONS: ____

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Company - Plant Bowen
JOB NO: ______ DATE: 9-20-72
OBSERVERS: C. E. Hickman

INSTRUMENTATION
SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE GR1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE GR1562-A SER. # 3122
OTHER: ______

PRIMARY NOISE SOURCE: Unit 1 cooling tower
EQUIP. MAKE & MODEL: Res. Cottrell Natural Draft
CLIENT DESIGNATION: Unit 1
OPERATING CONDITIONS: Unit 1 operating at rated load

Cooling tower is counterflow type

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
9	2:00p	I1	Railroad track - west	75	79	70	72	67	60	65	67	67	68	70
10		J1	25' farther west than I1	73	77	70	70	66	60	64	66	65	66	67
11		K1	North≈200' from base	74	81	71	72	71	64	63	66	67	67	65
12		L1	Between tower and plant	81	85	80	79	73	69	69	74	75	74	71
13		M1	At road	69	79	74	70	67	58	58	61	62	62	63

DIAGRAM- SHOW MEASURING LOCATIONS:

See sketch on page 1.

RECOMMENDATIONS: ______

NOISE SURVEY FORM

SOUTHERN SERVICES INC
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Co.-Plant Bowen
JOB NO: 024 DATE: 4-6-73
OBSERVERS: Hickman and Thompson

INSTRUMENTATION

SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE GR1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE GR1562-A SER. # 3122
OTHER: Windscreen

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
14:00	OK					

PRIMARY NOISE SOURCE: Unit 1 Cooling Tower
EQUIP. MAKE & MODEL Res. Cottrell Natural Draft
CLIENT DESIGNATION: Unit 1
OPERATING CONDITIONS:
Tests 1-5: Unit 1 operating at 695-700MW
Test 5A: Unit 1 off the line

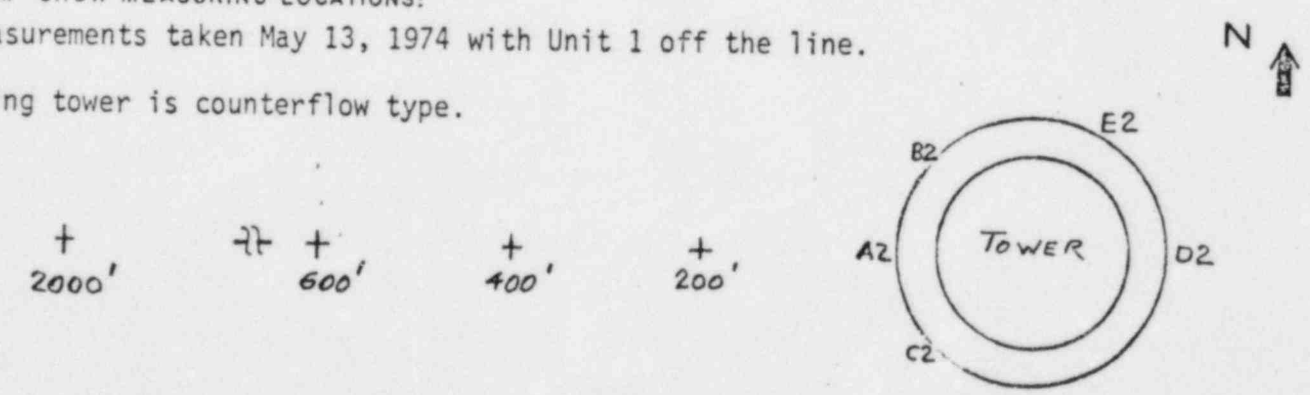
SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.: 31.5	63	125	250	500	1000	2000	4000	8000
1	14:00	A2	Rim of basin-West	85	86	65	74	68	68	77	78	77	78	79
2		B2	Rim of basin-Northwest	85	86	67	72	69	68	77	78	78	78	79
3		C2	Rim of basin-Southwest	85	86	67	72	67	68	77	78	77	78	79
4		D2	Rim of basin-East	86	87	75	80	72	70	77	77	77	78	79
5		E2	Rim of basin-At valve	95	96	76	81	84	84	87	90	89	85	82
5A	**	A2	Rim of basin-West	85	87	70	73	70	68	76	79	78	78	77

DIAGRAM - SHOW MEASURING LOCATIONS:

**Measurements taken May 13, 1974 with Unit 1 off the line.

Cooling tower is counterflow type.



RECOMMENDATIONS: ______

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Co.-Plant Bowen
JOB NO: ?24 DATE: 4/6/73
OBSERVERS: Hickman and Thompson

INSTRUMENTATION

SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE G R1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE GR1562-A SER. # 3122
OTHER: Windscreen

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

PRIMARY NOISE SOURCE: Unit 1 cooling tower
EQUIP. MAKE & MODEL: Res. Cottrell Natural Draft
CLIENT DESIGNATION: Unit 1
OPERATING CONDITIONS: Unit 1 operating at 695-700 MW

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

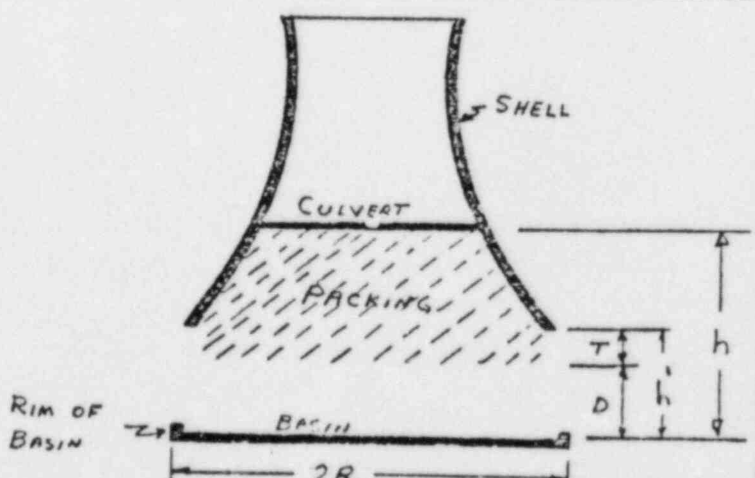
TEST NO.	TIME	POSITION	CONDITIONS West of Tower	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
6	14:25	F2	10' from rim of basin	83	84	66	73	64	64	74	75	75	75	75
7		G2	20' from rim of basin	80	81	67	75	64	62	71	72	72	72	73
8		H2	25' from rim of basin	79	80	65	74	63	61	68	71	72	72	73
9		I2	40' from rim of basin	78	79	64	74	64	61	68	69	71	71	71
10		J2	50' from rim of basin	77	78	63	72	65	60	67	68	70	70	69
11		K2	80' from rim of basin	74	75	62	67	63	58	64	66	67	67	66
12		L2	100' from rim of basin	73	75	63	68	66	57	63	65	67	67	64
13		M2	150' from rim of basin	71	74	63	71	61	55	62	64	64	64	69

DIAGRAM - SHOW MEASURING LOCATIONS:

See sketch on page 1

Descriptive Data: Counterflow tower

Water flow= 258,400 gpm
R=138'=42m
T=-2'=-0.61m
D=32'=9.75m
h=37'=11.3m
h'=30'=9.15m



RECOMMENDATIONS: ______

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Co.-Plant Bowen
JOB NO: 024 DATE: 4/6/73
OBSERVERS: Hickman and Thompson

PRIMARY NOISE SOURCE: Unit 1 cooling tower
EQUIP. MAKE & MODEL: Res. Cottrell Natural Draft
CLIENT DESIGNATION: Unit 1
OPERATING CONDITIONS: Unit 1 operating at 695-700 MW

INSTRUMENTATION
SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE GR1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE G R1562-A SER. # 3122
OTHER: Windscreen

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
16:00	OK					

TEST NO.	TIME	POSITION	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
			West of Tower											
14	15:00	N2	225' from rim (at road)	68	71	64	68	65	62	57	60	62	60	53
			Northwest of Tower											
15	15:30	O2	100' from rim of basin	72	76	69	70	66	61	63	64	65	65	61
16		P2	150' from rim of basin	70	76	68	73	66	60	60	63	64	63	56
17		Q2	200' from rim of basin	67	76	69	75	65	59	58	61	61	59	52
18		R2	300' from rim of basin	66	74	69	70	65	56	59	59	59	56	45
19		S2	400' from rim of basin	62	73	67	69	61	57	57	57	56	51	40

Sound pressure level, dB RE 20μ N/M² rms; octave band center frequency, Hz.

DIAGRAM - SHOW MEASURING LOCATIONS:

See sketch on page 1

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Co.-Plant Bowen
JOB NO: 040 DATE: 5/8/74
OBSERVERS: Hickman and Thompson

INSTRUMENTATION

	Type		
SLM	B&K 2209	SER. #	454249
TRANSDUCER	B&K 4145	SER. #	456988
ANALYZER	B&K 1613	SER. #	460875
CABLE		LENGTH	
CALIBRATOR	B&K 4220	SER. #	457476
OTHER	Windscreen		

PRIMARY NOISE SOURCE: Unit 2 Cooling Tower
EQUIP. MAKE & MODEL: Res.Cottrell Natural Draft
CLIENT DESIGNATION: Unit 2
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

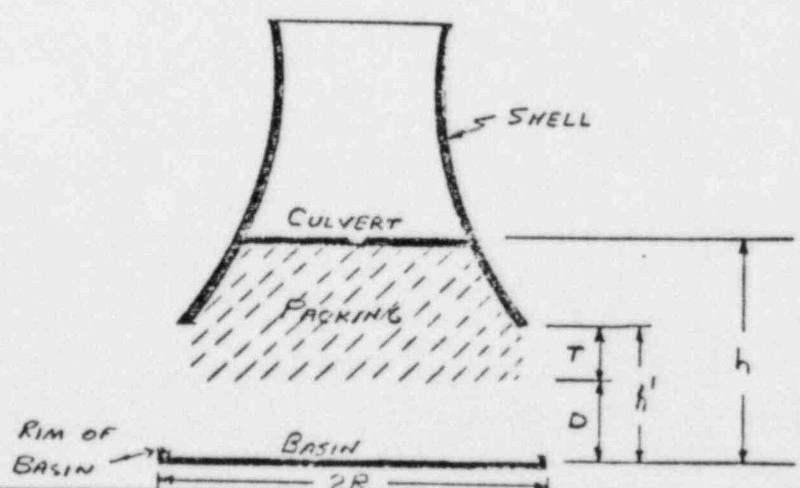
TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
16:10	OK					

TEST NO.	TIME	POSITION	CONDITIONS Southwest of Tower	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
1	16:20	A3	Rim of basin	84	89	70	72	70	69	78	79	77	77	76
2		B3	10' from rim of basin	82	89	73	73	68	67	74	77	75	74	73
3		C3	20' from rim of basin	78	81	65	72	69	64	71	72	72	72	70
4		D3	25' from rim of basin	78	80	67	74	70	63	69	71	72	72	70
5		E3	40' from rim of basin	76	79	64	72	64	62	66	69	70	69	67
6		F3	50' from rim of basin	74	79	63	70	64	61	65	67	68	68	66
7		G3	80' from rim of basin	73	76	62	72	62	57	63	66	67	67	63
8		H3	100' from rim of basin	72	75	63	70	66	60	63	65	66	65	61

DIAGRAM - SHOW MEASURING LOCATIONS:

Descriptive Data: Counterflow tower

Water flow=258,400 gpm
R=138'=42m
T=-2'=-0/61m
D=32'=9.75m
h=37'=11.3m
h'=30'=9.15m



RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Co.-Plant Bowen
JOB NO: 041 DATE: 5/20/74
OBSERVERS: Hickman and Thompson

INSTRUMENTATION

SLM: TYPE	B&K 2209	SER. #	454249
TRANSDUCER: TYPE	B&K 4145	SER. #	456988
ANALYZER: TYPE	B&K 1613	SER. #	460875
CABLE: TYPE		LENGTH	
CALIBRATOR: TYPE	B&K 4220	SER. #	457476
OTHER:	Windscreen		

PRIMARY NOISE SOURCE: Unit 3 Cooling Tower
EQUIP. MAKE & MODEL Res.Cottrell Natural Draft
CLIENT DESIGNATION: Unit 3
OPERATING CONDITIONS: Unit 3 off line
Cooling tower is counterflow type

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
10:00	OK				6-8	E

TEST NO.	TIME	POSITION	CONDITIONS East of Tower	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
1	10:05	A4	Rim of basin	82	86	80	73	71	68	73	76	76	76	75
2		B4	10' from rim of basin	81	85	80	73	70	65	72	75	74	74	73
3		C4	20' from rim of basin	79	83	80	73	69	63	68	72	72	73	72
4		D4	25' from rim of basin	77	83	80	74	67	62	66	69	71	71	71
5		E4	40' from rim of basin	75	80	75	72	63	59	62	65	68	69	68
6		F4	50' from rim of basin	74	79	76	73	65	58	63	65	67	68	67
7		G4	80' from rim of basin	72	79	72	71	65	55	62	64	66	67	65
8		H4	100' from rim of basin	71	79	74	69	63	59	60	63	64	65	61

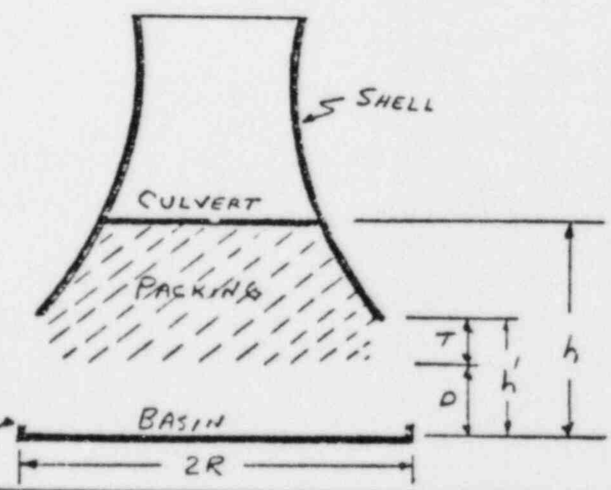
SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms; OCTAVE BAND CENTER FREQUENCY, Hz.

DIAGRAM- SHOW MEASURING LOCATIONS:

Descriptive Data: Counterflow tower

Water flow = 310,000 gpm=23,400 kg/sec.
R=158.5'=48.4m
T=-2'=-0.61m
D=36'=10.9m
h=44'=13.4m
h'=34'=10.4m

Approximately one-half of the total water capacity was by passed during this test.



RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Co, Plant Bowen
JOB NO: 041 DATE: 5/20/74
OBSERVERS: Hickman, and Thompson

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Unit 3 Cooling Tower
EQUIP. MAKE & MODEL: Res. Cottrell Natural Draft
CLIENT DESIGNATION: Unit 3
OPERATING CONDITIONS: Unit 3 off line

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
10:57	OK					
13:15	OK					

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.								
			East of Tower			31.5	63	125	250	500	1000	2000	4000	8000
9	10:30	I4	150' from rim of basin	69	78	72	69	62	54	59	62	63	63	61
10		J4	200' from rim of basin	66	75	72	65	62	51	57	60	61	60	55
11		K4	300' from rim of basin	62	78	69	66	58	50	52	55	57	57	51
12		L4	400' from rim of basin	60	77	69	65	59	49	52	55	55	54	47
13	10:55	M4	500' from rim of basin	58	73	67	65	59	45	45	48	48	50	40
14	13:25	N4	600' from rim of basin	53	74	67	64	65	53	46	47	45	40	37
15		O4	700' from rim of basin	52	72	69	63	54	50	48	44	43	39	28
16		P4	800' from rim of basin	51	74	67	62	54	50	48	44	38	36	28

DIAGRAM - SHOW MEASURING LOCATIONS:

RECOMMENDATIONS:

SS195-1-0

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Georgia Power Co.-Plant Bowen
JOB NO: 041 DATE: 5/20/74
OBSERVERS: Hickman and Thompson

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Unit 3 Cooling Tower
EQUIP. MAKE & MODEL: Res. Cottrell Natural Draft
CLIENT DESIGNATION: Unit 3
OPERATING CONDITIONS: Unit 3 off line

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
17:00	OK					

SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms

TEST NO.	TIME	POSITION	CONDITIONS East of Tower	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
17	13:45	Q4	900' from rim of basin	48										
18		R4	1000' from rim of basin	45										

DIAGRAM - SHOW MEASURING LOCATIONS:

RECOMMENDATIONS:

SOUND LEVELS MEASURED AT VARIOUS DISTANCES
FROM THE UNIT 1 NATURAL DRAFT COOLING TOWER
AT PLANT BOWEN

Distance from Rim, Feet	Sound Level, dBA
At rim	85
10	83
20	80
40	78
50	77
80	74
100	73
200	69
300	66
400	62
600	48-50
700	49-51
800	49-51
900	50
1000	50
1300	47-48
1400	43-45
1500	44
1600	41-45
1700	44
1800	43
1900	40
2000	42-44
2100	42
2300	41

SOUND LEVELS MEASURED AT VARIOUS DISTANCES
BETWEEN UNIT 1 AND UNIT 2 NATURAL DRAFT COOLING
TOWERS AT PLANT BOWEN

Distance from Rim of Unit 1 Tower, Feet	Distance from Rim of Unit 2 Tower, Feet	Sound Level, dBA
440	At rim	84
430	10	82
400	40	79
360	80	76
340	100	74
290	150	71
240	200	67
190	250	67
140	300	68
90	350	73
40	400	78
25	415	79
20	420	81
10	430	83
At rim	440	85

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co. - Crist Steam Plant
JOB NO: 021 DATE: 11-2-72
OBSERVERS: Hickman and Wright

INSTRUMENTATION
SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE GR1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE GR1562-A SER. # 3122
OTHER: ______

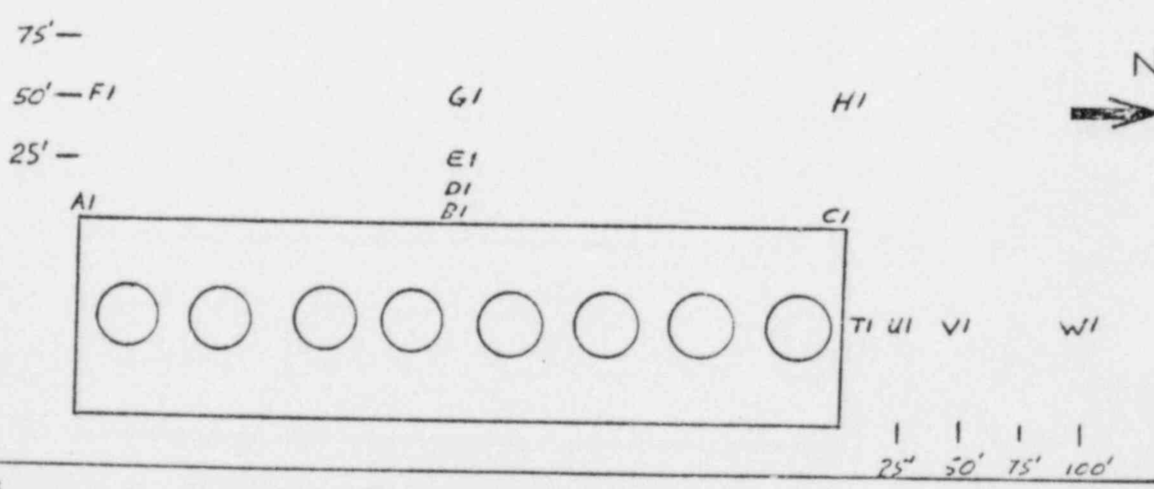
TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.
12:30	OK	75				

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley - 8 cells
CLIENT DESIGNATION: Unit 6 tower
OPERATING CONDITIONS: Unit 6 operating at at rated load.

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TEST NO.	TIME	POSITION	CONDITIONS West of Tower	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
1	13:00	A1	South end - 5'	84	95	86	82	81	79	74	73	74	76	79
2		B1	Center - 5'	84	95	89	82	83	82	75	75	75	77	80
3		C1	North end - 5'	83	93	82	80	82	80	74	73	73	76	80
4		D1	Center - 10'	83	94	84	80	81	80	74	74	74	76	79
5		E1	Center - 25'	82	92	86	80	79	79	73	73	73	73	76
6		F1	South end - 50'	77	88	80	80	74	75	70	70	69	67	70
7		G1	Center - 50'	80	92	82	80	75	76	72	72	72	70	73
8		H1	North end - 50'	78	90	82	79	75	75	70	70	70	69	72

DIAGRAM - SHOW MEASURING LOCATIONS:



RECOMMENDATIONS: ______

SS195-1-0

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co. - Crist Steam Plant
JOB NO: 021 DATE: 11-2-72
OBSERVERS: Hickman and Wright

INSTRUMENTATION

SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE GR1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE GR1562-A SER. # 3122
OTHER: ______

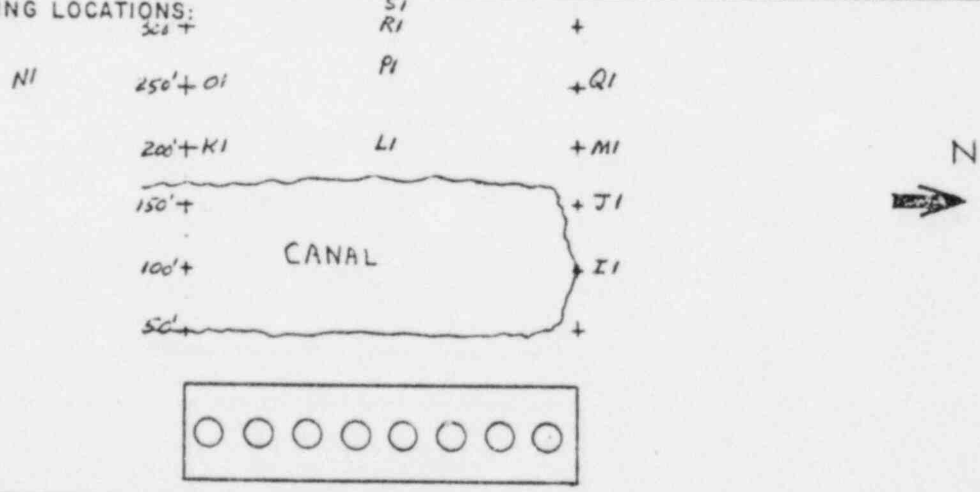
PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley - 8 cells
CLIENT DESIGNATION: Unit 6 tower
OPERATING CONDITIONS: Unit 6 operating at rated load.

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.: 31.5	63	125	250	500	1000	2000	4000	8000
			West of Tower											
9	13:15	I1	North end - 100'	73	83	78	76	70	66	67	66	65	64	64
10		J1	North end - 150'	72	84	74	76	71	64	66	65	64	63	63
--			West of Canal											
11		K1	South end ≈ 200'	70	81	74	74	72	67	64	64	63	62	62
12		L1	Center ≈ 200'	71	83	72	72	72	68	64	64	63	63	62
13		M1	North end ≈ 200'	70	80	75	75	72	66	65	64	63	63	62

DIAGRAM- SHOW MEASURING LOCATIONS:



RECOMMENDATIONS: ______

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co. - Crist Steam Plant

JOB NO: 021 DATE: 11-2-72

OBSERVERS: Hickman and Wright

INSTRUMENTATION

SLM: TYPE ______ SER. # ______

TRANSDUCER: TYPE GR1560-P6 SER. # 1950

ANALYZER: TYPE GR1558-BP SER. # 2279

CABLE: TYPE ______ LENGTH ______

CALIBRATOR: TYPE GR1562-A SER. # 3122

OTHER: ______

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

PRIMARY NOISE SOURCE: Cooling Tower

EQUIP. MAKE & MODEL: Marley - 8 cells

CLIENT DESIGNATION: Unit 6 tower

OPERATING CONDITIONS: Unit 6 operating at rated load.

SECONDARY NOISE SOURCE: ______

EQUIP. MAKE & MODEL: ______

CLIENT DESIGNATION: ______

OPERATING CONDITIONS: ______

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE $20\mu\ N/M^2$ rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.: 31.5	63	125	250	500	1000	2000	4000	8000
			West of Tower											
			Top of Bank											
14	13:40	N1	West of pumps ≈ 250'	69	79	73	79	70	65	65	63	61	59	55
15		O1	South end ≈ 250'	71	82	71	74	71	66	68	65	62	60	59
16		P1	Center ≈ 275'	72	83	75	77	71	66	68	66	64	63	61
17		Q1	North end ≈ 250'	71	84	73	74	70	65	67	65	63	62	61
18		R1	Center ≈ 300'	67	83	72	73	68	62	62	62	60	59	57
19		S1	Center ≈ 400' shielded											
			from tower by bank	61										

DIAGRAM - SHOW MEASURING LOCATIONS:

See Sketch on Page 2.

RECOMMENDATIONS: ______

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co. - Crist Steam Plant
JOB NO: 021 DATE: 11-2-72
OBSERVERS: Hickman and Wright

INSTRUMENTATION

SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE GR1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE GR1562-A SER. # 3122
OTHER: ______

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley - 8 cells
CLIENT DESIGNATION: Unit 6 tower
OPERATING CONDITIONS: Unit 6 operating at rated load.

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TEST NO.	TIME	POSITION	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
			North of Tower	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
[illegible]	14:15	T1	Center - 5'	68	81	74	71	71	67	63	61	59	57	56
21		U1	Center - 25'	65	82	76	71	71	65	58	56	55	54	53
22		V1	Center - 50'	64	79	75	71	70	66	59	56	54	53	51
23		W1	Center - 100'	61										

DIAGRAM - SHOW MEASURING LOCATIONS:

See Sketch on Page 1.

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co. - Crist Steam Plant

JOB NO: 021 DATE: 11-2-72

OBSERVERS: Hickman and Wright

INSTRUMENTATION

SLM: TYPE ______ SER. # ______

TRANSDUCER: TYPE GR1560-P6 SER. # 1950

ANALYZER: TYPE GR1558-BP SER. # 2279

CABLE: TYPE ______ LENGTH ______

CALIBRATOR: TYPE GR1562-A SER. # 3122

OTHER: ______

PRIMARY NOISE SOURCE: Cooling Tower

EQUIP. MAKE & MODEL: Marley - 8 cells

CLIENT DESIGNATION: Unit 6 tower

OPERATING CONDITIONS: Unit 6 operating at rated load.

SECONDARY NOISE SOURCE: Booster pumps

EQUIP. MAKE & MODEL: ______

CLIENT DESIGNATION: ______

OPERATING CONDITIONS: ______

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION	CONDITIONS South of Tower	SOUND PRESSURE LEVEL, dB RE 20μ N/M^2 rms A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz. 31.5	63	125	250	500	1000	2000	4000	8000
24	14:30	X1	Center - 10'	75	85	77	77	77	73	70	74	64	63	58
25		Y1	Near pumps ≈ 50'	81	89	81	80	79	80	77	76	70	66	58
26		Z1	Between booster pumps	87	94	85	82	82	88	86	83	76	73	63
27		A2	Booster pump motor	88	92	82	79	84	88	84	84	80	75	64
28		B2	Approx. 100' from tower	75	83	80	76	73	74	71	70	66	64	60
29		C2	Approx. 200' from tower	68	79	74	74	70	67	66	64	57	54	49

DIAGRAM - SHOW MEASURING LOCATIONS:

See Sketch on Page 1.

RECOMMENDATIONS: ______

SS195-1-0

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co. - Crist Steam Plant
JOB NO: 021 DATE: 11-2-72
OBSERVERS: Hickman and Wright

INSTRUMENTATION

SLM: TYPE		SER. #	
TRANSDUCER: TYPE	GR1560-P6	SER. #	1950
ANALYZER: TYPE	GR1558-BP	SER. #	2279
CABLE: TYPE		LENGTH	
CALIBRATOR: TYPE	GR1562-A	SER. #	3122
OTHER:			

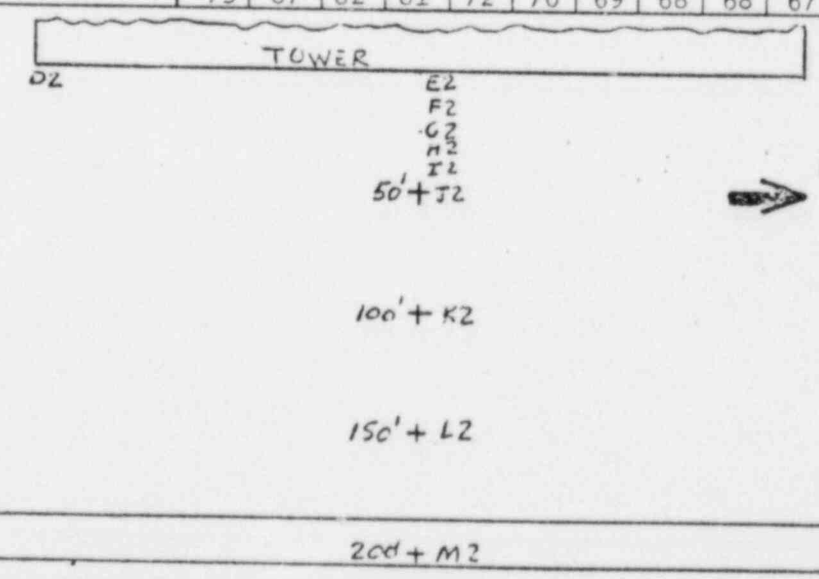
PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley - 8 cells
CLIENT DESIGNATION: Unit 6 tower
OPERATING CONDITIONS: Unit 6 operating at rated load.

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION	CONDITIONS East of Tower	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz. 31.5	63	125	250	500	1000	2000	4000	8000
30	15:10	D2	South end - 5'	84	95	84	81	82	81	75	74	75	76	79
31		E2	Center - 5'	84	95	88	81	82	81	76	75	75	76	79
32		F2	Center - 10'	83	95	88	80	83	82	76	74	74	75	78
33		G2	Center - 20'	82	90	88	82	80	81	75	73	73	73	77
34		H2	Center - 25'	81	94	83	82	80	80	74	72	72	72	75
35		I2	Center - 40'	79	93	84	83	77	77	73	71	72	70	73
36		J2	Center - 50'	79	89	83	83	75	76	71	71	71	69	72
37		K2	Center - 100'	75	87	82	81	72	70	69	68	68	67	68

DIAGRAM - SHOW MEASURING LOCATIONS:



RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co. - Crist Steam Plant
JOB NO: 021 DATE: 11-2-72
OBSERVERS: Hickman and Wright

INSTRUMENTATION

SLM: TYPE ______ SER. # ______
TRANSDUCER: TYPE GR1560-P6 SER. # 1950
ANALYZER: TYPE GR1558-BP SER. # 2279
CABLE: TYPE ______ LENGTH ______
CALIBRATOR: TYPE GR1562-A SER. # 3122
OTHER: ______

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley - 8 cells
CLIENT DESIGNATION: Unit 6 tower
OPERATING CONDITIONS: Unit 6 operating at rated load.

SECONDARY NOISE SOURCE: ______
EQUIP. MAKE & MODEL: ______
CLIENT DESIGNATION: ______
OPERATING CONDITIONS: ______

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.								
						31.5	63	125	250	500	1000	2000	4000	8000
			East of Tower											
38	15:40	L2	Center - 150'	72	86	80	79	71	65	64	64	64	63	64
39		M2	Center - 200'	69	84	78	79	70	64	62	62	62	61	60
			Top of Tower											
40		N2	North end	66	84	73	70	68	66	60	58	58	57	54
41		O2	South end	77	97	86	89	87	80	73	70	69	58	48
42		P2	Fan motor ≈ 5' west	93	101	93	94	88	88	88	89	85	81	75

DIAGRAM - SHOW MEASURING LOCATIONS:

RECOMMENDATIONS:

SOUTHERN SERVICES, INC.

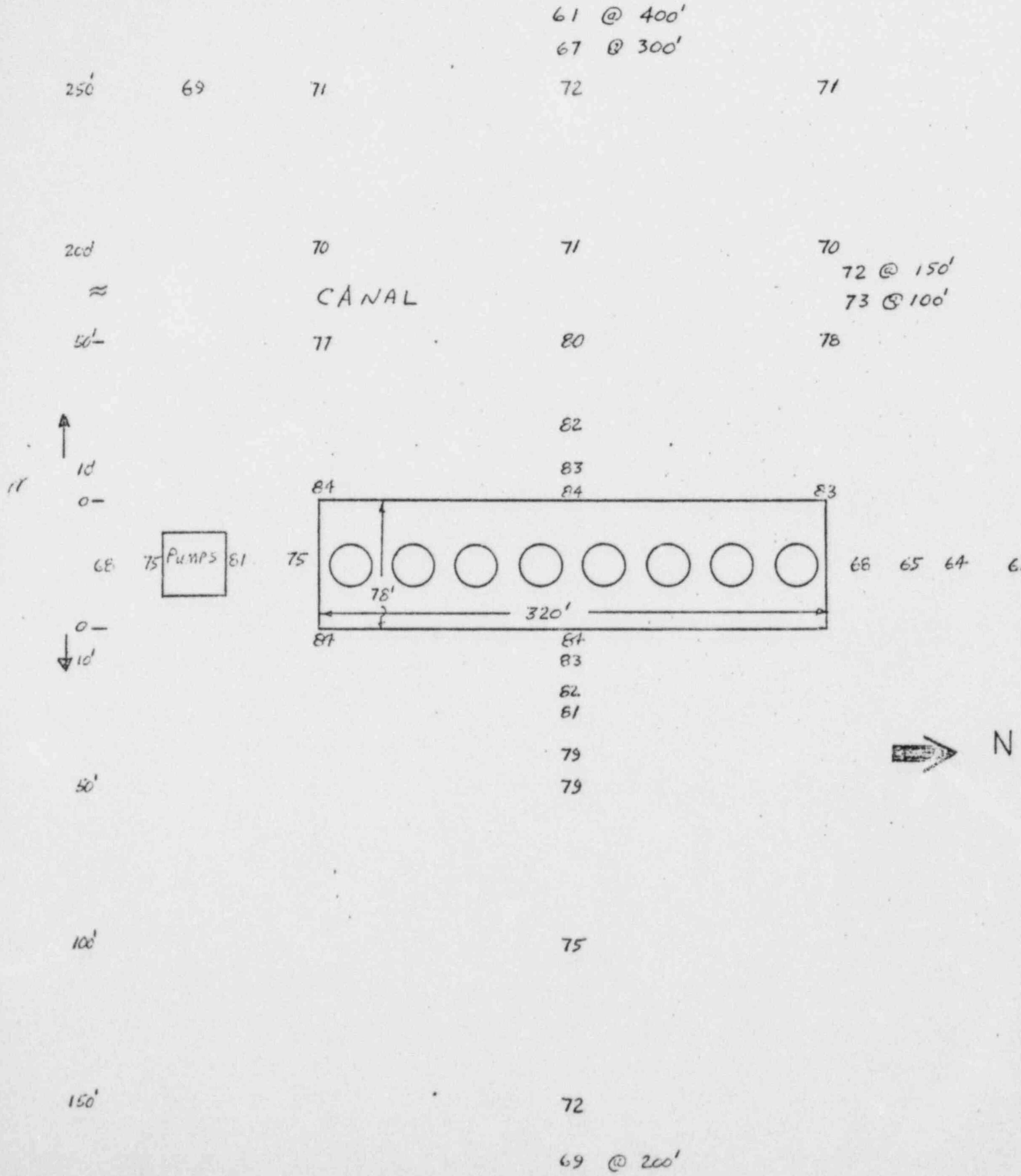
JOB Gulf Power Company - Crist Steam Plant

DESIGNED ________ DATE ________

CHECKED ________ DATE ________

SUBJECT Sound Level (dBA) Around Unit 6 Cooling Tower

SHEET 1 OF 1



NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: Gulf Power Co.-Crist Unit 7
JOB NO: 037 DATE: 2/13/74
OBSERVERS: Hickman, Thompson, and Czepluch

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 456988
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE LENGTH
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen & Random Inc. Corr.

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
11:00	OK					

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Mechanical draft
CLIENT DESIGNATION:
OPERATING CONDITIONS:

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms										
				A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz.								
			Cooling Tower			31.5	63	125	250	500	1000	2000	4000	8000
150	10:20	Q6	3' W. - ctr. of tower	84	94	86	87	86	84	79	76	76	76	77
151		R6	3' N. of tower	69	87	78	80	74	68	63	61	62	57	55
152		S6	3' E. - ctr. of tower	83	99	91	84	85	84	79	76	75	75	76
153		T6	3' S. of tower	78	89	84	79	79	73	73	74	70	70	65
154		U6	10' N. of CT pumps	85	94	87	84	85	84	81	79	76	73	73

DIAGRAM - SHOW MEASURING LOCATIONS:

Positions Q6-U6 are marked on blueprint D-19000.

RECOMMENDATIONS:

SOUND LEVEL SURVEY
UNIT 5 COOLING TOWER
PLANT JACK WATSON
MISSISSIPPI POWER COMPANY
GULFPORT, MISSISSIPPI

September 29, 1977

Charles E. Hickman
Research & Development Department
Southern Company Services, Inc.
Birmingham Alabama

INTRODUCTION

A sound level survey was conducted for Mississippi Power Company around the Unit 5 cooling tower at Plant Jack Watson on September 29, 1977. The major purpose of this survey was to document sound levels around the only round mechanical draft cooling tower within the Southern electric system.

Measurements were made using the A- and C- weighting networks and octave bands centered at ANSI Preferred Frequencies (ANSI Standard S1.6-1967(R1971)) from 31.5-8000 Hz. The sound level meter used meets the Type I specifications of ANSI Standard S1.4-1971. Instrumentation used during the survey is listed below.

Manufacturer	Type	Model No.	Serial No.
Bruel & Kjaer	Sound Level Meter	2209	454249
Bruel & Kjaer	Octave Band Analyzer	1613	460875
Bruel & Kjaer	Microphone	4145	455974
Bruel & Kjaer	Calibrator	4220	457476
Bruel & Kjaer	10' Cable	AO 0027	-

To supplement the sound level data, the following documents are included in this report.

1. Print E-PS-3014 which shows the location of the cooling tower relative to the plant and on which the measurement locations are marked.
2. Schematic View-Plan-Concrete Crossflow
3. Schematic View-Elevation-Concrete Crossflow
4. Various parameters, both operational and dimensional, for the tower.

SURVEY RESULTS

Sound level data measured around the Plant Jack Watson Unit 5 cooling tower are presented on six pages of "Noise Survey Forms." Unit 5 is a 500 MW, 2400 PSIG unit and the cooling tower is a Marley Round

Class 700 Mechanical Draft Crossflow type. The tower cools 172,000 GPM of water from 120^{o}F to 90^{o}F at a wet bulb temperature of 80^{o}F. During the survey Unit 5 was operating at 460 MW and 15 out of 16 fans were running.

The Marley Company supplied the following statement concerning sound levels in their bid.

"SOUND LEVELS - Predicted sound levels (dbA) at 5 ft. above ground level and specified distance from towers.

Distance	100'	500'	1000'	2000'	3000'	4000'	5000'
dbA	68	59	55	49	46	43	40

No contribution from ambient design features of the base tower including high efficiency fans, low pressure drop system, and round partitionless plenum structure ensure minimum noise characteristics. Should further noise reduction be required due to site requirements, treatment would be determined as a function of location of sensitive area or areas, amount of reduction required and the frequencies to be attenuated. Treatment as established by the foregoing could consist of barrier walls, or attenuation baffles in the source - receiver path."

Due to the location of (1) the main plant with its exterior equipment, (2) the ash pond and (3) a spray module cooling canal for another unit, the number of traverses for obtaining meaningful data was quite limited (See Print E-PS-3014). Also, distances of approximately 300 feet along these traverses were maximums before the noise from external sources such as forced draft and induced draft fans became clearly audible.

From the Noise Survey Forms the following observations can be made.

1. Sound levels agreed within 2 dBA at every point along two traverses from the tower.

2. At the basin rim, 84-85 dBA was measured.

3. At 100 feet from the basin rim, a sound level of 72 dBA was measured. The Marley prediction was 68 dBA. It should be noted that the original design specified 13 fans. To improve the performance of the tower, 3 additional fans have been added (See Schematic View-Plan-Concrete Crossflow-Drawing No. 73-41622).

4. The sound level between the booster pumps located 40 feet from the basin rim was 86 dBA which was 1-2 dBA higher than sound levels measured at the basin rim. As a result, sound levels were approximately 2 dBA higher at distances of 40-100 feet from the pumps when compared to sound levels at equivalent distances from the basin rim along traverses not affected by the pump noise.

5. Octave band sound levels measured at the basin rim, at 100 feet from the rim and at 200 feet from the rim are plotted on Figure 1. No discrete tones were audible nor evident from these data.

Descriptive data and engineering information for the particular cooling tower investigated are included in this report. Perhaps this information will be useful in the development or verification of an equation to estimate sound power radiated by the round cooling tower.

SUMMARY

Based on the sound level results and the location of the round cooling tower on the plant site at Plant Jack Watson, no community noise complaints related to cooling tower noise are anticipated. Measured sound levels are comparable to those measured near other mechanical draft towers within the Southern electric system. One obvious exception, however, is that the round tower does not exhibit the near-field directivity observed with conventional mechanical draft systems.

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: MPCo - Plant Jack Watson
JOB NO: 070 DATE: 9/29/77
OBSERVERS: Hickman and Newton

INSTRUMENTATION
- SLM: TYPE B&K 2209 SER. # 454249
- TRANSDUCER: TYPE B&K 4145 SER. # 455974
- ANALYZER: TYPE B&K 1613 SER. # 460875
- CABLE: TYPE B&K LENGTH 10'
- CALIBRATOR: TYPE B&K 4220 SER. # 457476
- OTHER: Windscreen

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley Round Tower
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS: Unit 5 operating at 460 MW; cooling tower operating with 15 of 16 fans on

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
8:00	OK	78	90		0-6	

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz: 31.5	63	125	250	500	1000	2000	4000	8000
1	8:05	A1	Basin rim	85	93	90	87	83	81	77	76	77	80	80
2		B1	3' from rim	82	92	91	86	80	79	75	74	74	77	77
3		C1	6' from rim	81	90	90	85	80	76	73	72	72	75	75
4		D1	10' from rim	80	89	86-90	85	79	76	72	71	72	75	75
5		E1	12' from rim	80	90	89	85	79	76	72	71	71	74	75
6		F1	20' from rim	78	88	85-94	82-88	78	74	70	68	69	73	73
7		G1	24' from rim	77	88	86-91	82-88	78	75	70	68	68	71	69
8		H1	40' from rim	75	89	84-90	82-88	77-82	74	70	66	67	70	67

DIAGRAM - SHOW MEASURING LOCATIONS:

NOTES:

1. See Southern Services Dwg. No. E-PS-3014 for sound level measurement locations.
2. See Marley Company Dwgs. No. 73-41622 and 73-41623 for details of the cooling tower construction.

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: MPCo - Plant Jack Watson
JOB NO: 070 DATE: 9/29/77
OBSERVERS: Hickman and Newton

INSTRUMENTATION

SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 455974
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE B&K LENGTH 10'
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley Round Tower
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS: Unit 5 operating at 460 MW; cooling tower operating with 15 of 16 fans on

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
9	8:45	I1	48' from rim	75	88	85-91	81-87	78	73	69	65	66	69	66
10		J1	80' from rim	73	87	82-90	81-85	77	70	67	64	64	67	64
11		K1	96' from rim	72	86	80-86	81-85	76-79	70	66	63	63	66	63
12		L1	100' from rim	72	86	80-88	81-84	75-79	70	66	62	63	65	62
13		M1	150' from rim	69	84	80-85	78-82	74-78	68	63	60	61	63	50
14		N1	160' from rim	69	85	77-83	79	76	68	63	60	61	63	60
15		O1	192' from rim	68	84	80	77-82	74	66	62	58	59	62	58
16		P1	200' from rim	67	83	81	77-81	74	65	62	58	58	62	57

DIAGRAM - SHOW MEASURING LOCATIONS:

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: MPCo - Plant Jack Watson
JOB NO: 070 DATE: 9/29/77
OBSERVERS: Hickman and Newton

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 455974
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE B&K LENGTH 10'
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley Round Tower
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS: Unit 5 operating at 460 MW; cooling tower operating with 15 of 16 fans on

SECONDARY NOISE SOURCE: FD and ID fans
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS:

TEST NO.	TIME	POSITION	CONDITIONS	SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms: A SCALE LEVEL	OVER ALL LEVEL	OCTAVE BAND CENTER FREQUENCY, Hz: 31.5	63	125	250	500	1000	2000	4000	8000
17	9:45	Q1	300' from rim	63	82	75-80	78	71	63	57	54	54	56	51
18		R1	320' from rim	63	80	80	73-78	71	65	58	54	54	56	51
19		S1	384' from rim	63	80	78-81	72-77	72-76	65	58	55	54	55	50
20		T1	400' from rim	63	78	78	72-76	72	65	58	57	54	55	49
21		U1	450' from rim	63	79	78	72	73	65	59	54	54	53	47

DIAGRAM - SHOW MEASURING LOCATIONS:

R1. Plant visible, Unit 5 fans audible from approximately 300' and beyond.

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: MPCo - Plant Jack Watson
JOB NO: 070 DATE: 9/29/77
OBSERVERS: Hickman and Newton

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER # 455974
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE B&K LENGTH 10'
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley Round Tower
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS: Unit 5 operating at 460 MW; cooling tower operating with 15 of 16 fans on

SECONDARY NOISE SOURCE:
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION:
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	%RH	MMHG	WIND MPH	WIND DIR.

TEST NO.	TIME	POSITION	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
22	13:10	A2	Basin rim	84	94	86-92	86	82	82	77	76	76	77	75
23		B2	3' from rim	82	92	87	87	80	77	74	73	73	74	72
24		C2	6' from rim	80	91	89	87	80	76	73	72	71	72	71
25		D2	10' from rim	78	90	86-91	84	79	76	72	71	70	72	70
26		E2	12' from rim	78	91	84-90	83	79	76	71	70	70	72	70
27		F2	20' from rim	77	89	85-90	85	80	75	71	68	68	71	69
28		G2	24' from rim	76	89	84-90	84	79	75	71	68	68	71	68
29		H2	40' from rim	75	89	85-91	83	78	74	71	66	67	69	67

DIAGRAM - SHOW MEASURING LOCATIONS:

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: MPCo - Plant Jack Watson
JOB NO: 070 DATE: 9/29/77
OBSERVERS: Hickman and Newton

INSTRUMENTATION
SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 455974
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE B&K LENGTH 10'
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley Round Tower
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS: Unit 5 operating at 460 MW; cooling tower operating with 15 of 16 fans on

SECONDARY NOISE SOURCE: FD and ID fans
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS:

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
14:00	OK	85			0-6	

TEST NO.	TIME	POSITION	CONDITIONS	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz								
30	13:35	I2	48' from rim	75	86	86-90	83	78	73	70	66	66	69	66
31		J2	80' from rim	73	87	85-90	82	77	71	68	63	64	66	63
32		K2	96' from rim	72	86	82-88	83	77	70	67	64	63	66	63
33		L2	100' from rim	72	87	82-87	83	76	70	66	63	63	65	62
34		M2	150' from rim	70	85	80-86	82	76	68	65	61	61	63	59
35		N2	160' from rim	68	85	87	80	75	67	62	60	60	62	58
36		O2	192' from rim	68	84	83	81	73	66	62	58	59	62	57
37		P2	200' from rim	68	84	80-85	79-84	75	67	63	60	59	62	58

DIAGRAM - SHOW MEASURING LOCATIONS:

P2. Plant visible, Unit 5 fans audible from approximately 200' and beyond.

RECOMMENDATIONS:

NOISE SURVEY FORM

SOUTHERN SERVICES INC.
P.O. Box 2625
BIRMINGHAM, ALABAMA 35202

CLIENT: MPCo - Plant Jack Watson
JOB NO: 070 DATE: 9/29/77
OBSERVERS: Hickman and Newton

INSTRUMENTATION

SLM: TYPE B&K 2209 SER. # 454249
TRANSDUCER: TYPE B&K 4145 SER. # 455974
ANALYZER: TYPE B&K 1613 SER. # 460875
CABLE: TYPE B&K LENGTH 10'
CALIBRATOR: TYPE B&K 4220 SER. # 457476
OTHER: Windscreen

PRIMARY NOISE SOURCE: Booster pumps
EQUIP. MAKE & MODEL:
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS: Both pumps on

SECONDARY NOISE SOURCE: Cooling Tower
EQUIP. MAKE & MODEL: Marley Round Tower
CLIENT DESIGNATION: Unit 5
OPERATING CONDITIONS: Unit 5 operating at 460 MW; cooling tower operating with 15 of 16 fans on

TIME	CALIBRATION	TEMP.	% RH	MMHG	WIND MPH	WIND DIR.
12:30	OK	85			0-6	

TEST NO.	TIME	POSITION	CONDITIONS Booster Pumps	A SCALE LEVEL	OVER ALL LEVEL	31.5	63	125	250	500	1000	2000	4000	8000
				SOUND PRESSURE LEVEL, dB RE 20μ N/M² rms		OCTAVE BAND CENTER FREQUENCY, Hz.								
38	12:35	A3	3' N of pump	83	93	88	88	86	83	82	78	70	70	65
39		B3	Between pumps	86	94	89	88	88	87	84	84	71	68	66
40		C3	3' S of pump	83	93	89	88	87	82	82	78	70	71	69
41		D3	20' from CL of pumps	79	88	86	84	79	77	76	76	65	64	60
42		E3	40' from CL of pumps	75	90	85	84	80	73	72	73	64	65	61
43		F3	60' from CL of pumps	74	86	83-88	82	79	73	69	69	64	64	61
44		G3	80' from CL of pumps	73	86	83	81	78	73	68	68	62	64	60
45		H3	100' from CL of pumps	72	84	84	80	78	73	67	64	62	62	58

DIAGRAM - SHOW MEASURING LOCATIONS:

RECOMMENDATIONS:

K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 5493

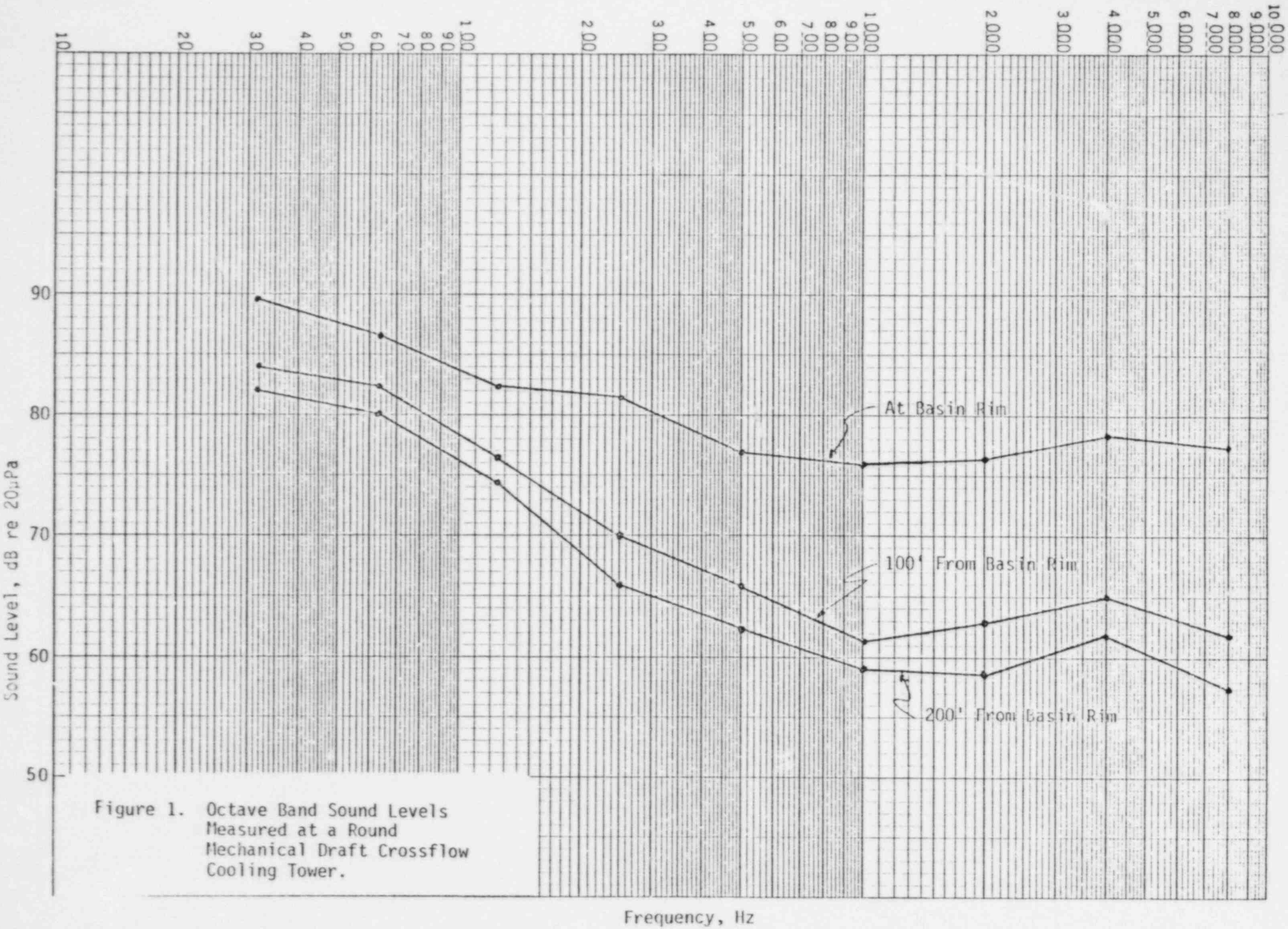


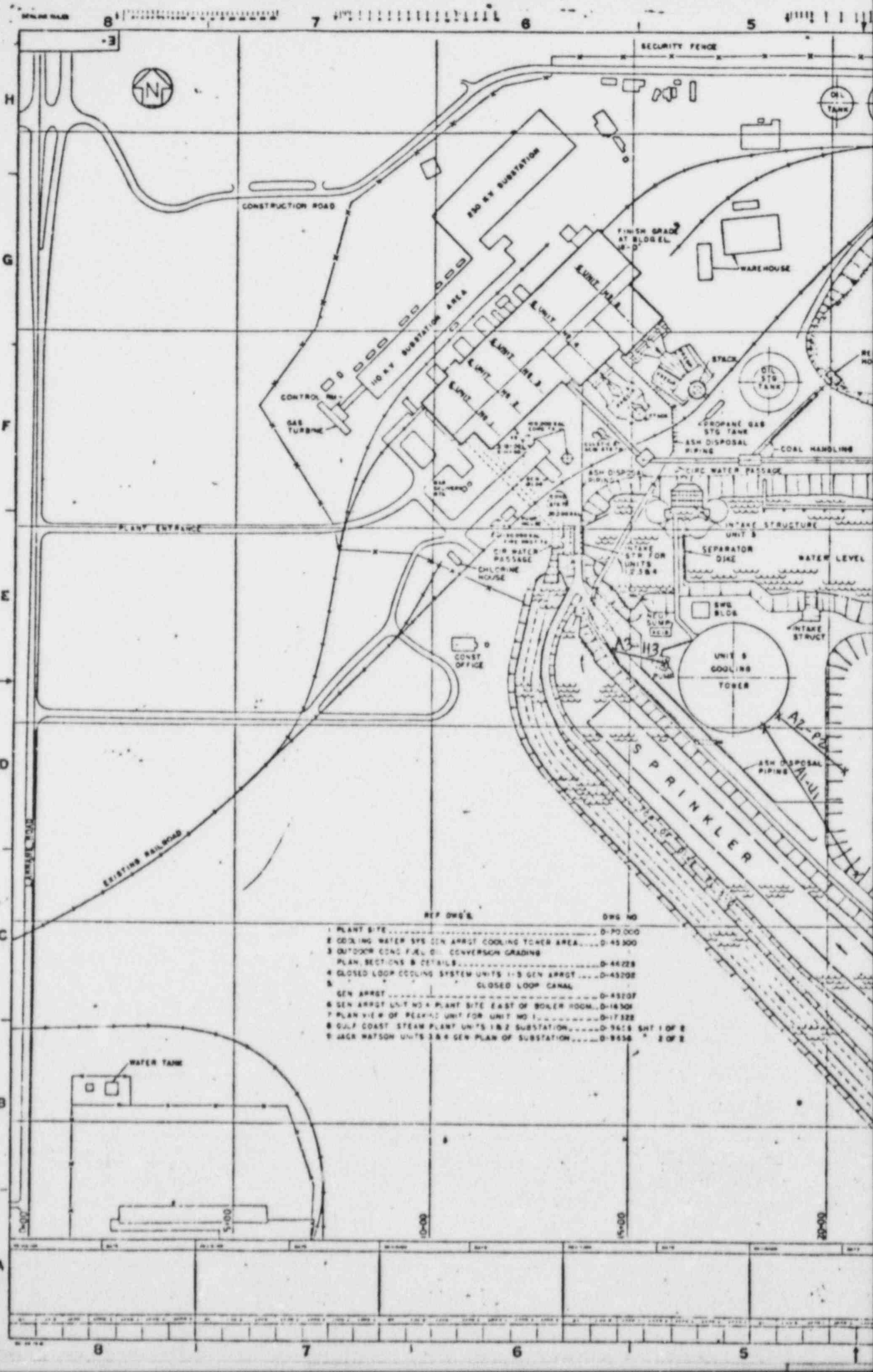
Figure 1. Octave Band Sound Levels Measured at a Round Mechanical Draft Crossflow Cooling Tower.

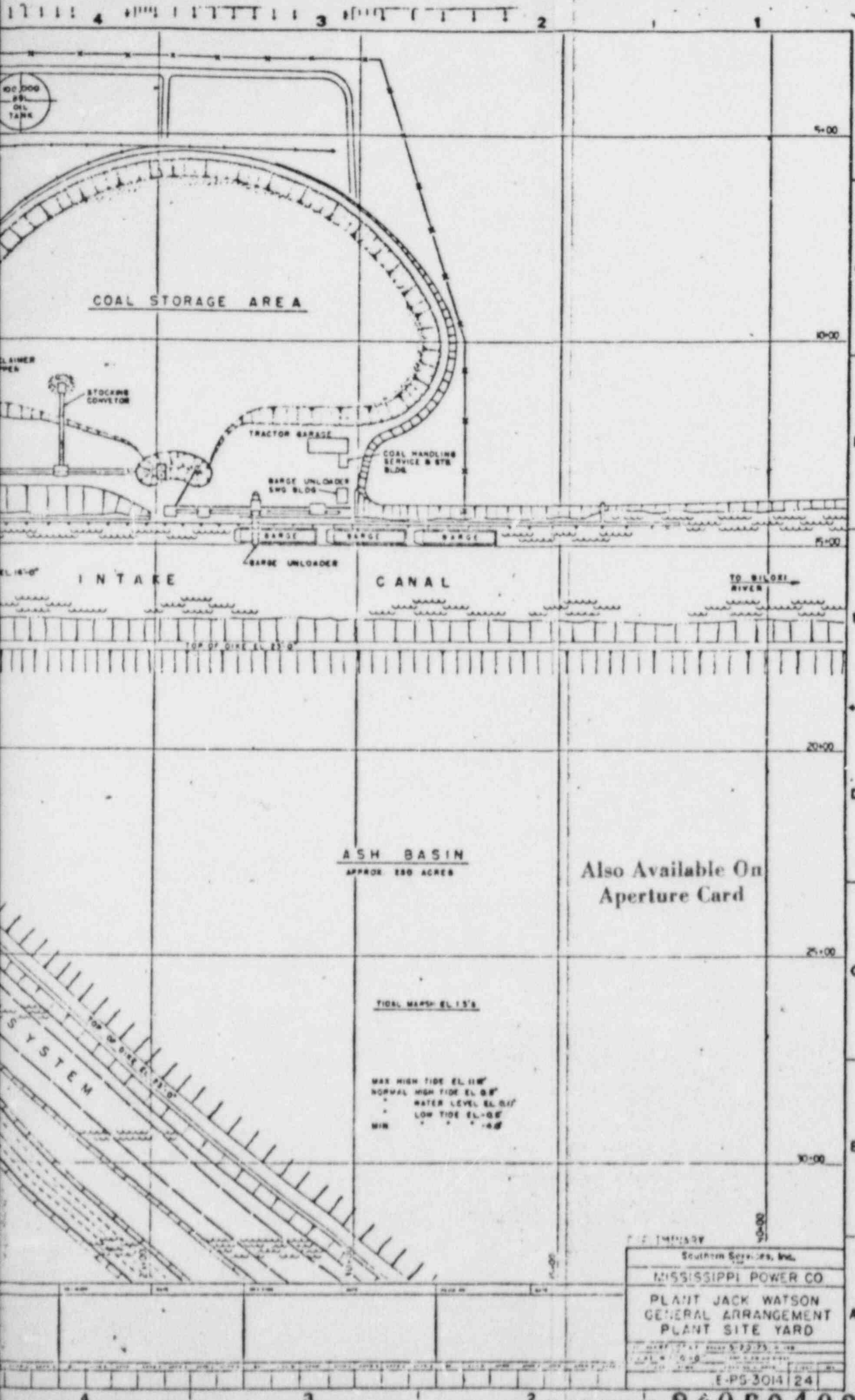
DESCRIPTIVE DATA AND ENGINEERING INFORMATION

The following descriptive data and engineering information are furnished in connection with Unit 5 at Plant Jack Watson

1.	Type of tower	Mechanical Draft
2.	Crossflow or counterflow	Crossflow
3.	Water flow from tower - gpm	172,000
4.	Temperature of water to tower - ^{o}F	120
5.	Temperature of water from tower - ^{o}F	90
6.	Design wet bulb temperature - ^{o}F	80
7.	Range - ^{o}F	30
8.	Approach - ^{o}F	10
9.	Orientation of tower	Refer to: Southern Services Dwg. No. E-PS-3014 Marley Dwg. No. 73-41622
10.	Pumping head required above sill at design conditions - ft	43.9
11.	Mean fill cross section area - ft^2	16,000
12.	Depth of fill section - ft	42
13.	Volume of fill section - ft^3	672,000
14.	Splash area - ft^2	448,000
15.	Fill wetted surface - ft^2	896,000
16.	Tower loading (per unit of splash area or wetted surface) - gpm/ft^2	0.384
17.	Outside diameter of tower - ft	287 (Refer to Marley Dwg. No. 73-41623)
18	Overall height of tower - ft (above sill)	59.8 (Refer to Marley Dwg. No. 73-41623)
19.	Height of distribution headers above sill - ft (to flume water level)	42.8 (Refer to Marley Dwg. No. 73-41623)
20.	Material of fill	Corrugated Asbestos Cement Board per ASTM C221 (Type II Cement; Autoclaved)

21.	Material of support system	Precast concrete with noncombustible glass reinforced polyester grids
22.	Air inlet area - ft^2	33,000
23.	Stack exhaust velocity - ft/sec	30
24.	Number of cells required	One
25.	Number of fans required	16
26.	Fan manufacturer	Marley
27.	Diameter of fan - ft	28
28.	Fan blade material	Glass Reinforced Polyester
29.	Fan blade tip speed - ft/sec	201
30.	Fan speed - rpm	137
31.	Gear reducer manufacturer	Marley
32.	Brake horsepower per fan - hp	147
33.	Motor description	150 Hp, 3/60/550, 1800 RPM, 445TS, TEFC


SECURITY FENCE
OIL TANK
CONSTRUCTION ROAD
230 K.V. SUBSTATION
FINISH GRADE AT BLDG EL
WAREHOUSE
110 K.V. SUBSTATION AREA
UNIT NO. 5
UNIT NO. 4
UNIT NO. 3
UNIT NO. 2
UNIT NO. 1
CONTROL
GAS TURBINE
STACK
OIL STG TANK
PROPANE GAS STG TANK
ASH DISPOSAL PIPING
COAL HANDLING
CIRC WATER PASSAGE
INTAKE STRUCTURE UNIT 5
PLANT ENTRANCE
SEPARATOR DIKE
WATER LEVEL
CIR WATER PASSAGE
CHLORINE HOUSE
INTAKE STR FOR UNITS 1,2,3 & 4
SWG BLDG
INTAKE STRUCT
UNIT 5 COOLING TOWER
CONST OFFICE
A3-113
A2-P2
A1-U1
ASH DISPOSAL PIPING
SPRINKLER
EXISTING RAILROAD
WATER TANK
REF DWG'S
DWG NO
1 PLANT SITE D-70 000
2 COOLING WATER SYS GEN ARRGT COOLING TOWER AREA D-45300
3 OUTDOOR CONC FUEL OIL CONVERSION GRADING
PLAN, SECTIONS & DETAILS D-44228
4 CLOSED LOOP COOLING SYSTEM UNITS 1-5 GEN ARRGT D-45202
5 " " " " CLOSED LOOP CANAL
GEN ARRGT D-45207
6 GEN ARRGT UNIT NO 4 PLANT SITE EAST OF BOILER ROOM .. D-16304
7 PLAN VIEW OF PEAKING UNIT FOR UNIT NO 1 .... D-17328
8 GULF COAST STEAM PLANT UNITS 1 & 2 SUBSTATION ...... D-9616 SHT 1 OF 2
9 JACK WATSON UNITS 3 & 4 GEN PLAN OF SUBSTATION ...... D-9656 " 2 OF 2



Also Available On Aperture Card

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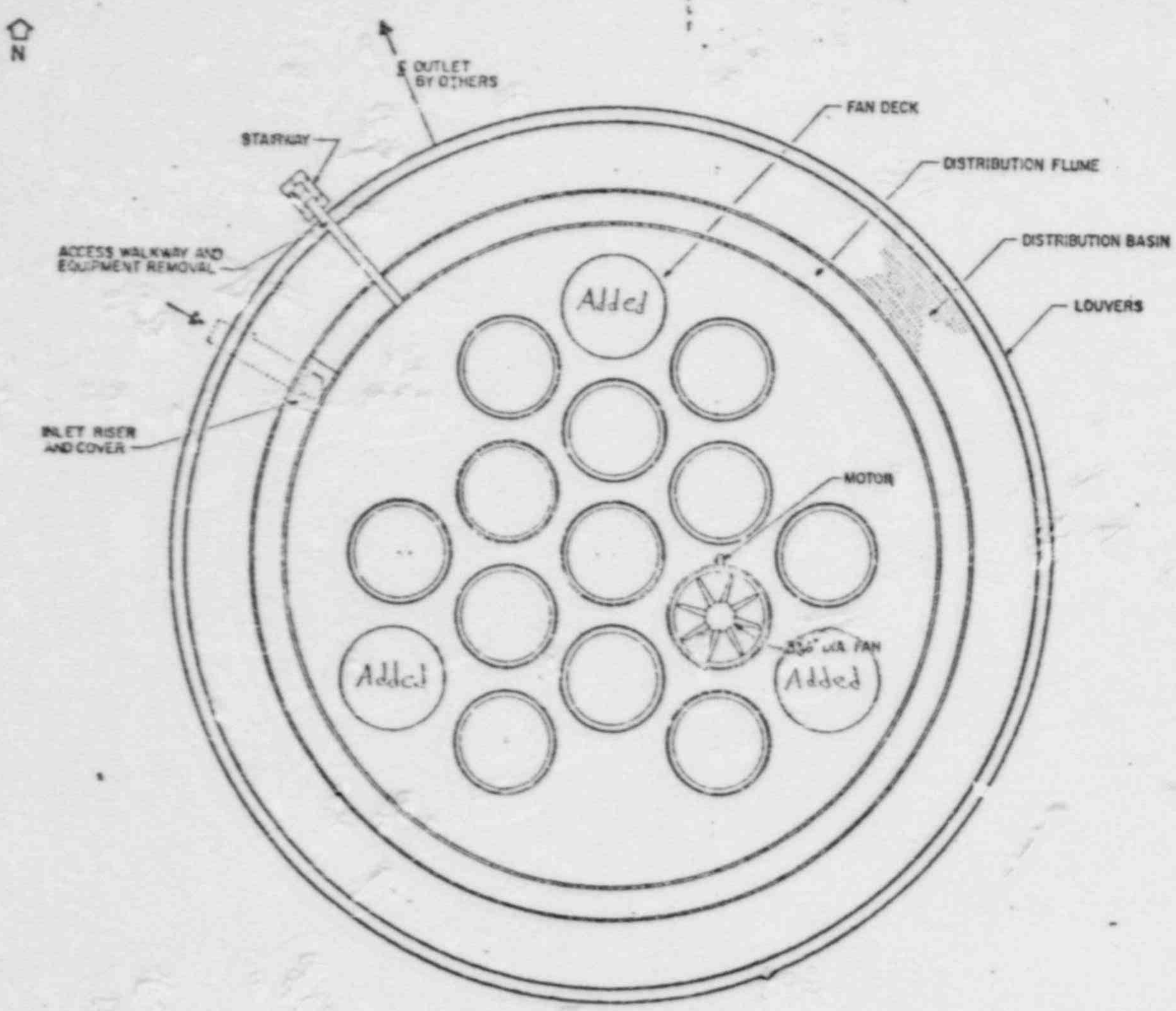
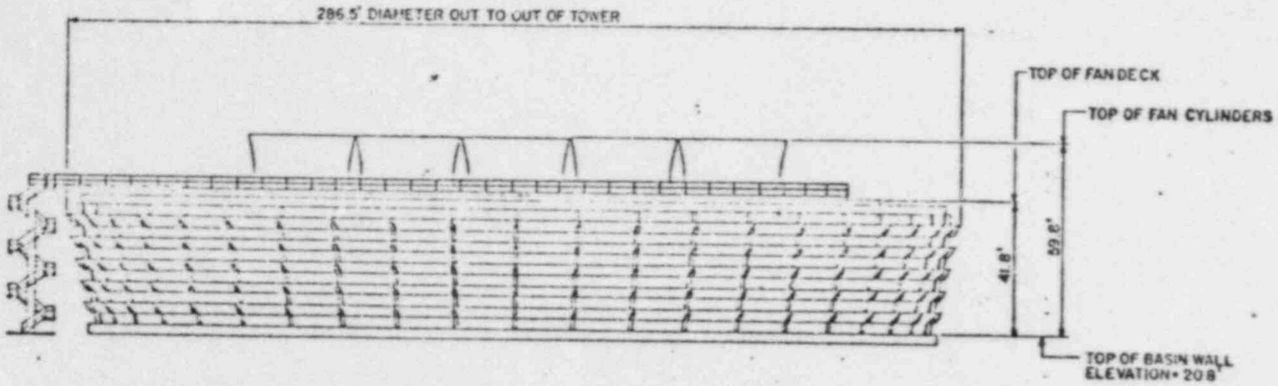


PLAN

MISSISSIPPI POWER COMPANY
JACK WATSON PLANT
UNIT NO. 5

SCHEMATIC VIEW-PLAN
CONCRETE CROSSFLOW
THE MARLEY COMPANY

Drawing No. 73-41622



ELEVATION

MISSISSIPPI POWER COMPANY
JACK WATSON PLANT
UNIT NO. 5

SCHEMATIC VIEW - ELEVATION
CONCRETE CROSSFLOW

No. 73-41623

16 March 1973, Volume 179, Number 4078 SCIENCE

Propagation of Environmental Noise

More theoretical and experimental work could permit the prediction and subsequent control of environmental noise.

R. H. Lyon

Sound propagation is a general term that embraces the myriad of processes that occur in the transmission of acoustical energy from the place where it is generated to the point of observation. It includes the phenomena of refraction and geometric spreading, air and surface absorption, and scattering, reflection, and diffraction. All of these are important and particular examples of environmental noise propagation. The main problem in studies of noise propagation is that of determining which mechanisms are dominant in any particular situation.

The process of observing the sound by measuring it with a microphone or listening to it has little interaction with the propagation process, except that the strategy for making accurate observations is affected by our understanding of the propagation. There is not such a distinct separation between the processes of generation and propagation, however. The location of a source may affect both its sound power output and the transmission of the sound. Location affects the directivity of the sound source.

As an example, let us consider an ordinary fan operating in an open window. If the window is closed, the sound power radiated by the fan may increase because of the impact of flow upon the window pane, while the propagation path is also very markedly changed. Nevertheless, with most environmental noise, we assume that the sound output of the sources such as cars, jackhammers, and aircraft remains nearly unchanged as the sources move about.

The author is in the department of mechanical engineering at the Massachusetts Institute of Technology, Cambridge 02139.

The Phenomena That Comprise Propagation

The physical phenomena that are associated with sound propagation have been mentioned. Most practical situations include at least two or three of these phenomena. In this section, I give a brief description of each phenomenon and an indication of the kind of propagation problems in which it occurs.

Geometric spreading. This refers to the spreading of sound energy in space as a result of the expansion of the wave fronts, as shown in Fig. 1. It (almost) always causes an attenuation in sound levels by a certain amount when the propagation distance is changed by a fixed ratio. This ratio is ordinarily the distance doubled, abbreviated *dd*. Geometric spreading is generally considered to be independent of frequency and has a major effect in all situations of sound propagation (*1*).

Refraction. Refraction is the bending of sound rays caused by gradual changes in the speed of sound that are brought about principally by wind and temperature gradients in the atmosphere (*2*). Humidity also changes the speed of sound by changing the average molecular weight of the gas. Since the speed of sound is shown by $c = (\lambda RT/M)^{1/2}$, the effects on sound of changes in molecular weight, M, and temperature, T, are equivalent (R is the gas constant and λ is the ratio of specific heat). This equivalence is expressed by deriving an "acoustic temperature" for purposes of sound speed calculation (*3*). An example of refraction with temperature lapse and wind gradient is shown in Fig. 2. Refraction is important when the change in the path of sound may affect shielding of the observer from the source as shown in Fig. 3. Refraction effects are usually only observed for distances of a few hundred meters (1 foot = 0.3 meter) or more.

Air absorption. The absorption of sound in air is caused by (shear) viscosity, heat conduction, and molecular vibrational relaxation (*4*). The effect is commonly expressed as a change in sound level in a fixed distance. Commonly chosen distances are 1000 feet or 1 kilometer. The attenuation is frequency dependent and typically amounts to a few decibels per 1000 feet in the most audible frequency bands, 500 hertz to 2 kilohertz. This form of attenuation is most significant for the noise of aircraft landing and taking off or for other noise problems in which the propagation distance is rather long.

Surface absorption. Sound levels are affected by surface reflections in two distinct ways. When the source and receiver are both close to the ground, the ray reflected from the ground may interfere destructively with the direct ray as shown in Fig. 4 (*5*). This effect is usually noticeable over ranges of propagation from a few hundred to a few thousand feet in the frequency range from 100 to 500 hz. When the source is very close to the ground as in the case of snowmobiles or lawnmowers, the effect is even more important and can affect sound levels very close to the source. An example of this attenuation effect is shown in Fig. 5 (*6*).

Sound levels are also affected by the loss of energy upon reflection. This process is called surface absorption in acoustics. The effect is of paramount importance in room acoustics for the sound strikes the walls many times (*7*). In outdoor propagation the losses upon reflection are also important. When sound propagates along a city street, for example, multiple reflections from building faces occur. Sound that would reach the observer if the buildings were perfect mirrors is reduced because of absorptive reflection losses (*8*) and because of redirection of the acoustical energy. The redirection of sound is more properly included in the subject of scattering.

Scattering. When sound waves encounter a region of inhomogeneity in the medium (a local variation in sound speed or air density) some of their energy is redirected into many other directions. This process is called scattering and is distinct from refraction and reflection. In those processes, the redirection is essentially into one direction. Scattering is produced in environmental noise situations by turbulence (*9*), rough or irregular surfaces (*10*), and obstacles in the path such as trees and other vegetation (*11*). In industrial situations pipes, machines, and other obstacles scatter and redirect the acoustical energy.

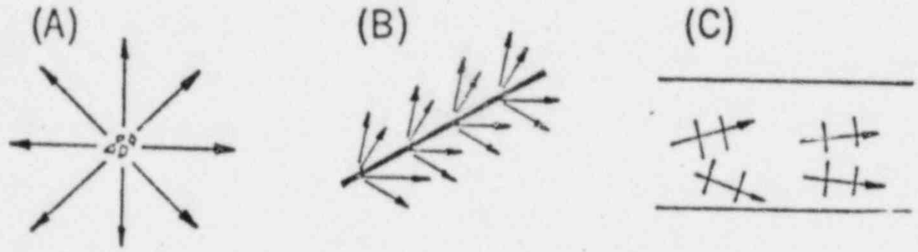


Fig. 1. Geometric divergence of sound waves and resulting attenuation. (A) Spherical spreading, 6 dB/*dd*; (B) cylindrical spreading, 3 dB/*dd*; (C) sound in channel, 0 dB/*dd*.

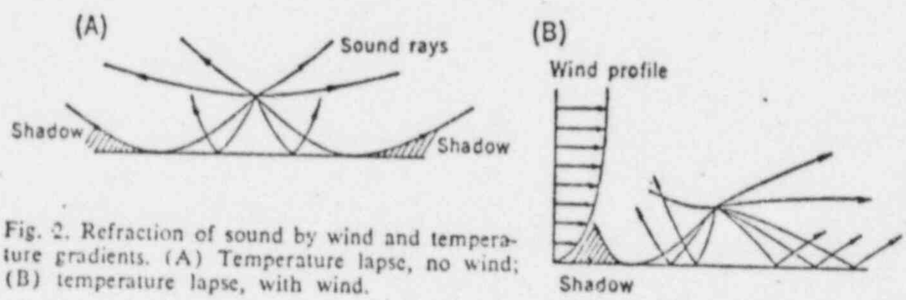


Fig. 2. Refraction of sound by wind and temperature gradients. (A) Temperature lapse, no wind; (B) temperature lapse, with wind.

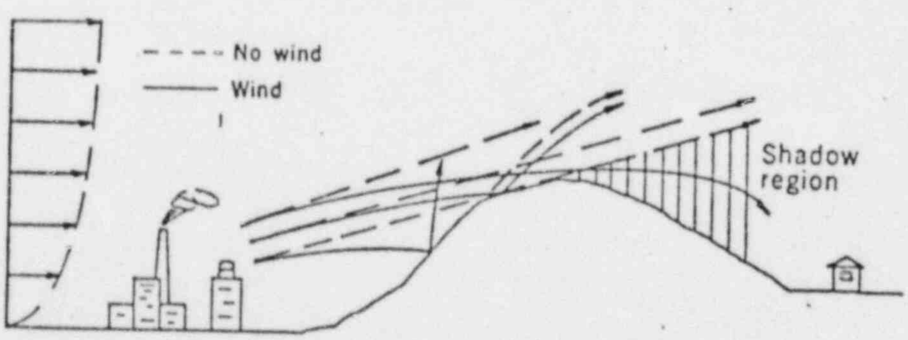


Fig. 3. Destruction of barrier effect by wind refraction.

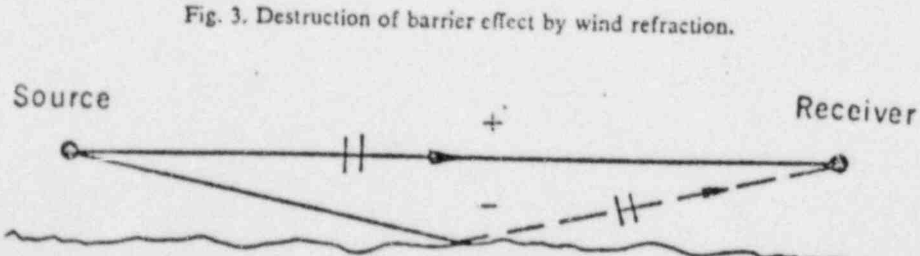


Fig. 4. Reflection of grazing wave from ground showing possibility of destructive interference.

Scattering can cause quite remarkable changes in sound levels. When sound would normally be shielded from some region by a barrier, turbulence can cause the effectiveness of the barrier to be greatly reduced. Barriers rarely provide more than 15 dB of shielding in field situations because of the sound energy scattered into the shadow region by turbulence (*12*). On the other hand, turbulence scattering does not cause losses in energy great enough to compete with other attenuation processes in directly illuminated regions.

The scattering of sound by rain, fog, or snow, for example, at ordinary frequencies is not great enough to be significant (*13*). The effects of precipitation are far more important in changing sound transmission by changing the humidity and the temperature distributions in the lower atmosphere.

Reflection. When the sound encounters a surface that is several wavelengths in extent, the entire wave is redirected. This results in increased sound levels for positions illuminated by the rebounding wave and reduced levels at other positions, as shown in Fig. 6. Barriers reduce sound levels by reflection; the orchestra shell of a concert hall enhances sound by the same process.

As mentioned before, reflections are of particular importance in propagation along city streets. Experiments show that significant amounts of sound energy may still be present after a wave makes four or five reflections from the surfaces of a building. In most outdoor situations, however, reflection and scattering take place simultaneously because of the rough texture of the surfaces. The actual absorption of sound from masonry walls is generally less than 10 percent, but the amount redirected by scattering may be significantly greater than this (*14*).

Diffraction. In a shielded region (behind a house that faces a busy street, for example) sound levels may be limited by diffraction. Diffraction and scattering are very similar phenomena. Diffraction may, in fact, be defined as the scattering that occurs at a region of inhomogeneity at the bounding surface of the medium, such as where there is a rapid change in impedance or radius of curvature (*4*, p. 449). Thus, a finite wall forms a boundary to the medium. The flat surfaces of the wall result in reflection, but the sharply curved surfaces at the edges of the wall cause the scattering termed "diffraction."

Because the pipes and machines in

a factory might be defined as part of the "bounding surface" of the medium, it is evident that the distinction between scattering and diffraction may be somewhat artificial. Diffraction in outdoor sound propagation is important in transmitting sound energy into shielded areas, although the absolute amount of sound power redistributed by diffraction is quite small.

Wall transmission. The phenomena already discussed are of principal importance to people outside of buildings. Because most people spend much of their time within buildings, the transmission of sound through the exterior walls, windows, and doors of these buildings is of prime importance in establishing the noise levels to which people are exposed. In this article I discuss the prediction of noise levels outside buildings; once the exterior sound levels are known it is possible to predict the noise within buildings by reference to standard transmission values (*15*).

To show how the various phenomena that affect sound propagation enter into practical noise situations I will consider several examples. In each example there are aspects to the propagation that are well understood and there are others that are uncertain. Active research is under way in this field and we may hope that some of the uncertainties will soon be removed.

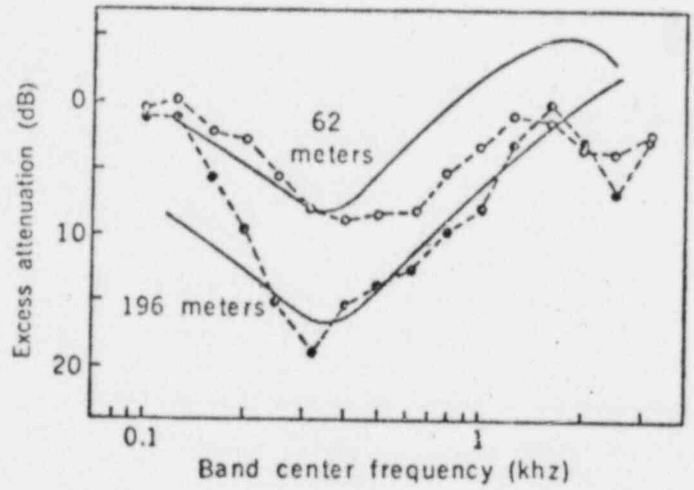
Aircraft Take-Off Noise

In Fig. 7 an aircraft is shown taking off along the path ABC, and we are interested in the sound levels heard by the observer at O. The principal determinants of the sound at O are (i) the power of the source (in octave bands), (ii) the directivity of the source, (iii) geometric spreading, (iv) air absorption, and (v) ground reflection (*16*). Determinants (i) and (ii) are source characteristics and not propagation effects; (iii) and (iv) are the principal propagation effects that must be evaluated for this situation; (v) is important, but is easy to evaluate—the ground reflection simply adds 3 dB to the received sound level at a normal height of the observer's ear above the ground.

Geometric spreading for "point" sources is simply 6 dB of loss per doubling of distance (6 dB/*dd*). Refraction of the sound may change this slightly. There is more uncertainty in the air absorption. In calculations of aircraft noise at distances of several kilometers, the sound levels in the higher frequency bands have been consistently overestimated (*17*), probably because of incorrect estimates of air absorption at these frequencies.

Recent investigations of air absorption over wide ranges of frequency and humidity indicate that the role of nitrogen in producing attenuation in the lower frequency bands has been underestimated (*18*). Although a single relaxation theory of molecular vibration for oxygen and nitrogen molecules appears to fit the form of the absorption data, the role of water molecules in catalyzing this energy transfer alters the temperature dependence of the absorption (*19*). Also, the reaction can become complicated in that there may be several different modes of energy transfer to the molecules. These multiple transfer processes together with the catalyzing effect of the water vapor tend to conceal the temperature de-

Fig. 5. Excess attenuation caused by ground absorption; receiver height, 1.83 meters; source height, 1.52 meters. Symbols: ○, theoretical data; ●, experimental data. Parameter on curves is source-receiver distance. [From Delaney and Bazley (*6*); courtesy of the *Journal of Sound and Vibration*]



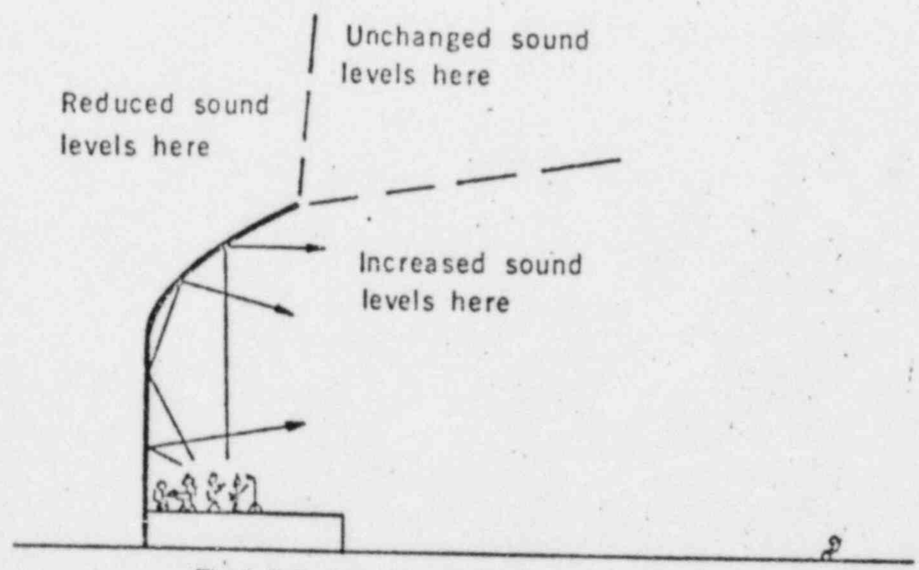


Fig. 6. Reflection of sound energy by orchestral shell.

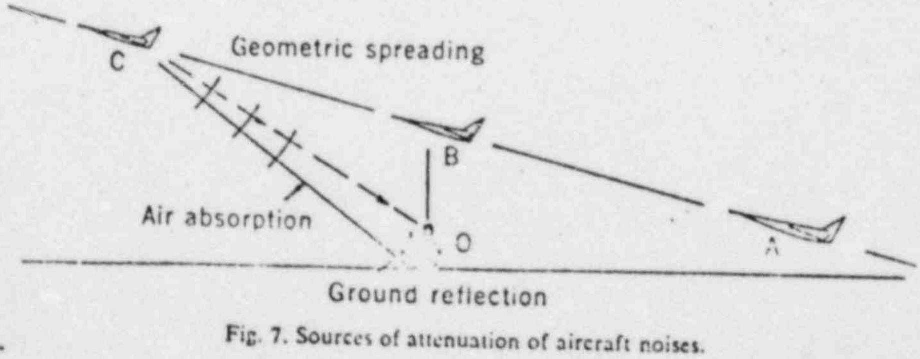


Fig. 7. Sources of attenuation of aircraft noises.

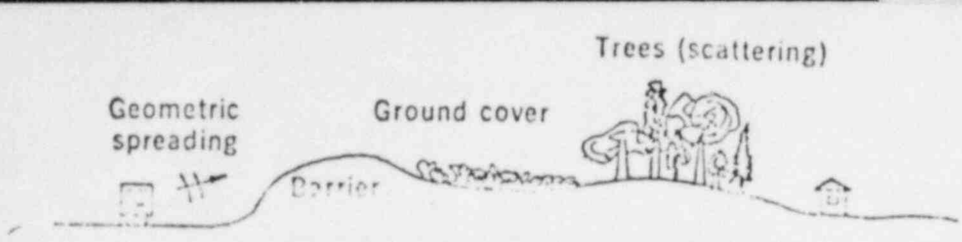


Fig. 8. Sources of attenuation of traffic noise.

pendence. Thus, although air absorption is well understood at a temperature of 20°C it is not understood how the absorption should vary as one departs from this temperature.

Highway Noise

The noise from trucks or automobiles is generated close to the ground and usually the receiver is also near the ground. Figure 8 shows some topographical features that may occur near a highway and affect sound propagation. These features act as barriers to the sound. Ground cover and trees may produce low-frequency attenuation as a result of absorptive reflection and sound scattering.

Attenuation caused by geometric spreading of the sound waves from a single vehicle increases at 6 dB/*dd*. A line of traffic, on the other hand, produces an average noise level that decays at 3 dB/*dd* (*20*). Theoretical and experimental studies have been conducted on the statistics of noise from lines of traffic composed of different numbers of the principal classes of noise sources: trucks, passenger cars, and motorcycles (*21*). In making a precise determination, a different geometric attenuation factor must be applied to each statistic of the noise field. This is an area in which it is very difficult to separate source characteristics from "propagation."

The attenuation produced by topographical features is treated as a simple barrier diffraction problem in most calculations (*22*). Much more work needs to be done in this area since earth berms, road cuts, and barrier walls can be used in the control of noise from roadways. The use of standard diffraction formulas for "thick barriers" such as buildings or elevated roadways is not a resolved issue at present. In most calculations the thick barrier is treated as a single, equivalent, taller, thin barrier (*23*); in other calculations the theory of double diffraction is applied (*24*). It is evident, however, that a rounded earth berm covered with short vegetation is not adequately accounted for if it is treated as a simple rigid wedge. The use of diffraction studies of absorbing cylinders would represent a step forward (*25*), but studies of diffraction by layered cylinders would be even better.

There has also been a series of studies regarding the attenuating power of trees, but the results of these studies are inconclusive (*26*). Most acousticians agree that (aside from esthetics) ringing one's yard with trees presents very little barrier to neighborhood noise. Studies of propagation through various kinds of wooded regions show attenuation factors that differ by a factor of 10. Even the proper form of attenuation dependence is uncertain.

An interesting study of sound attenuation by vegetation and ground was reported recently by Aylor (*27*). In this study, major mechanisms of attenuation by vegetations were identified as scattering by leaves, stems, and trunks, and ground interference. Aylor attempted to identify the relative importance of various mechanisms and presented some theoretical considerations that support his conclusions. Although a fully developed scattering theory could probably account for such data, the problem of presenting the results in a manner intelligible and useful to noise control engineers would remain.

Thus road traffic noise over open flat ground is reasonably well understood. Reduction in noise levels can certainly be achieved by the use of topographical features, including ground cover, but the quantitative prediction of such reduction may be substantially in error.

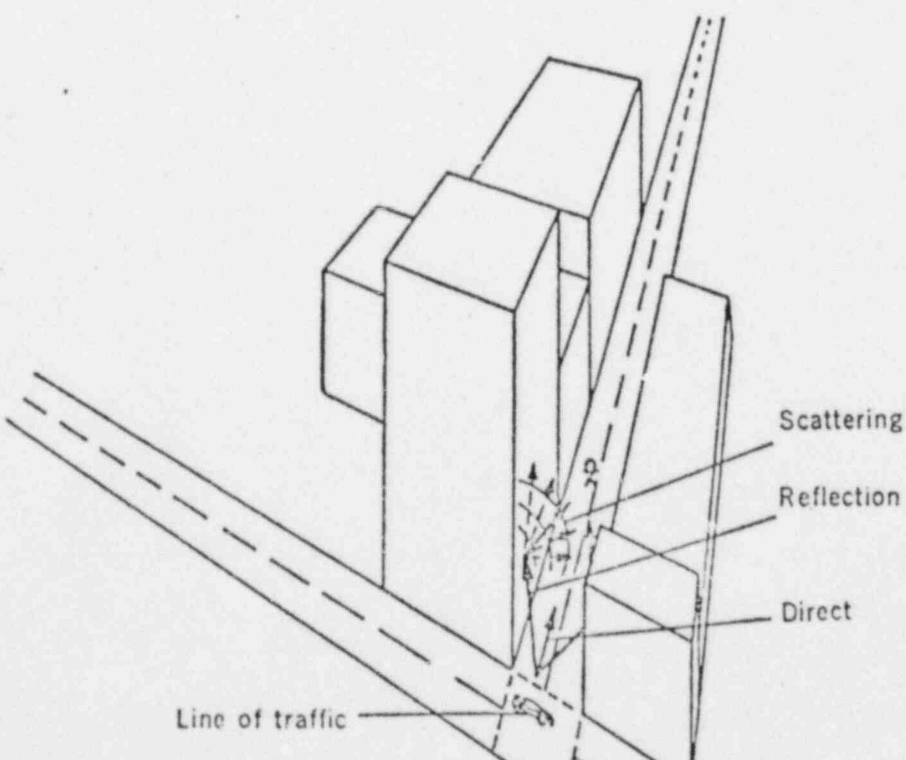
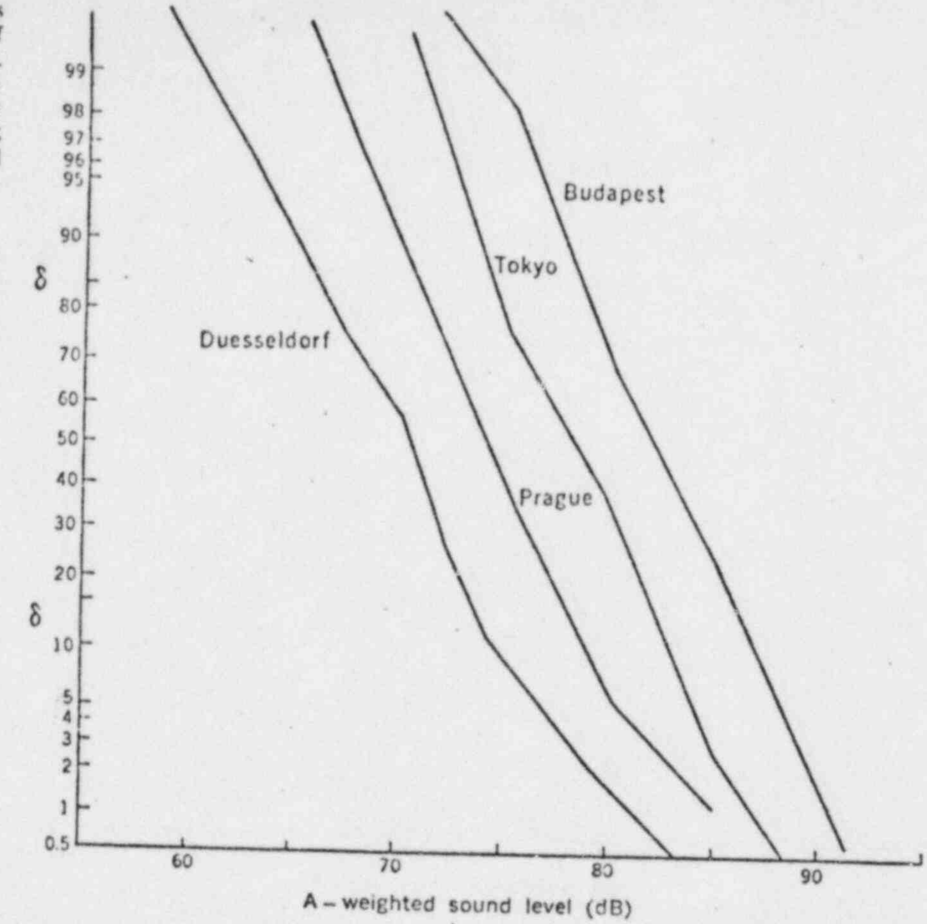


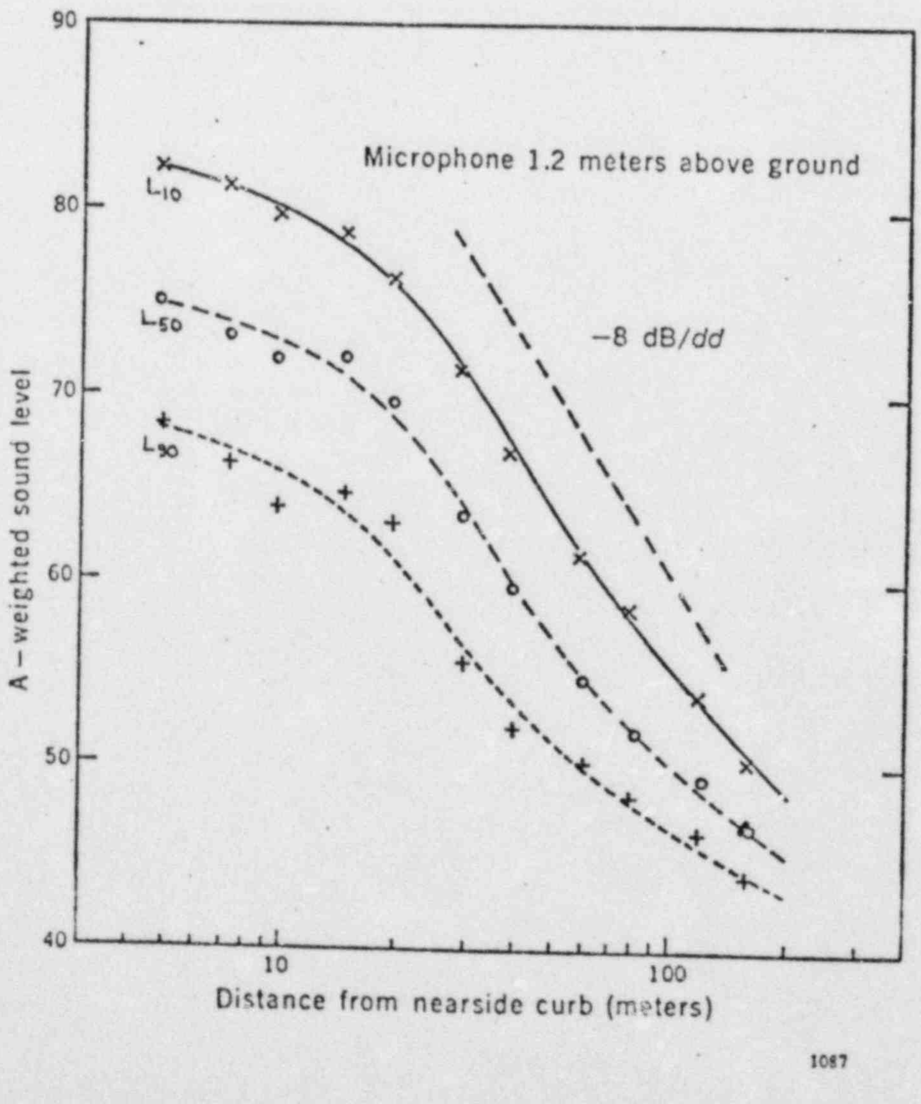
Fig. 9. Transmission phenomena in urban traffic noise.

Noise Propagation in the City

A possible reaction to this topic is that urban noise does not have to propagate—it is everywhere! It is true that noise sources in the city are ubiquitous. Nevertheless, there are quiet regions in which the background noise is set by the general distribution of noise sources throughout a city (*28*). There are also quiet streets that have intrusive noise that is produced on a busy adjoining thoroughfare (*29*). In addition, there are intensive noise sources that may dominate the sound in a particular vicinity, even in busy areas. In all of these situations, the combined effects of reflection and shielding by buildings are

Fig. 10 (top). Cumulative distributions of traffic noise in the loudest streets of Budapest, Tokyo, Prague, and Duesseldorf. Fig. 11 (bottom). Variation of noise level with distance from main road along cross road. [From Delaney *et al.* (29); courtesy of National Physical Laboratory]





(aside from geometric spreading) the dominant propagation factors that determine sound levels for the observer.

As an example, let us consider sound propagation along a city street as shown in Fig. 9. Specular reflection from building facades produces the effect of an infinite line of sources (images of the real source) which has a 3 dB/*dd* decay along the street. The scattering and capture of sound by the spaces between building acts as an absorption effect, which means that the sound levels should eventually decay at 6 dB/*dd* (8). In fact, however, experiments show that there are ranges near the source along which the sound decays at 7 to 8 dB/*dd*, a rate that is impossible with a model that contains only specular reflection and absorption (29). This discrepancy can probably be accounted for by the effect of scattering both in enhancing the sound levels near the source and acting as an excess absorption effect, but such conclusions are very speculative.

Propagation in Relation to Noise Criteria

If it is important for us to identify the major features of propagation for various environmental noise situations, it is equally important that we understand what questions we should ask the propagation model once the phenomena are identified. Our asking the right questions depends on our knowing what are the features of the noise pattern in space and time that are related to annoyance, task interference, loss of hearing acuity, or some other undesirable effect. Thus, although we can separate the physical processes of propagation and observation, we cannot make such a separation when we have to predict noise impact. Most calculations of propagation losses for sound waves are computed or expressed for average sound levels. When other statistics of the noise are of interest, the effect of propagation is not the same as it is for erage values. Thus, by examining some of the measures of noise levels that are based on these statistics we can formulate some questions that might be asked of the propagation model.

Psychoacoustic Criteria

The term "criterion" in environmental matters is used in two ways (*30*). First, it is an expression of an allowable limit for some effect, for example, "my understanding of speech should not be interfered with more than 10 percent of the time," or "my hearing should not be impaired so much, that while I may not be able to hear some musical features very well, my understanding of speech should be unaffected." On the basis of laboratory and psychoacoustical field tests, these "performance criteria" are then translated into physical measures such as speech interference level (SIL) or A-weighted sound levels (measured by the "A" setting on a sound level meter) according to the Occupational Safety and Health Act of 1970 (*1*, p. 546). Second, the numerical values of the disturbance of these physical scales that correspond to the performance criteria are also referred to as "criteria." Although this has often resulted in confusion, it is very difficult to change the dual usage of the term.

Psychoacoustical criteria have to do with both the physical effects of sound on the biological or nervous system and the subjective aspects of sound. Physical effects include such criteria as loss of hearing, disorientation, and pain. This class of criteria is not generally thought to be of prime significance in urban noise. The subjective effects of sound, which include loudness, annoyance, speech interference, startle, and task interference, are so termed because the degree to which they are apparent depends upon the attitude of the listener toward the noise and on his familiarity with it. The establishment of standards for urban noise must include consideration of several subjective criteria and not just a single one.

The proliferation of scales for measuring noise appropriate to these criteria is a cause of some embarrassment to acousticians. It is the source of the "alphabet soup" one encounters in the literature on environmental noise: the A-weighted sound level [units dB(A)]; perceived noise level, PNL (with various suffixes, prefixes, and subscripts to note corrections for duration, presence of tones, and impulse); noise criterion curves (NC curves); noise exposure forecast (NEF); composite (or community) noise rating (CNR); community noise equivalent level (CNEL), and so on. Out of these, the simple A-weighted reading of the sound level meter appears to be gaining credibility as a general scale for noise. The A-weighting filter in the meter gives an importance to various frequency components of the noise in accordance with the loudness sensitivity of the ear at moderate sound levels.

The A-weighted sound pressure level, $L_p{}^A$, will vary in time and place, however, in a random—or at least unpredictable—manner. In the following discussion I will assume that the "A" notation is understood; that is, all levels are A-weighted. The variability of the noise has been shown to have an influence on its acceptability. Studies of traffic and aircraft noise have led to a rating scale for noise called the noise pollution level, L_{NP}, that takes account of this variability (*31*).

It is given by

$$L_{NP} = L_{50} + (L_{10} - L_{90}) + \frac{1}{60}(L_{10} - L_{90})^2 \qquad (1)$$

when the A-weighted sound levels are distributed in an approximately normal distribution (the tendency of environmental levels of pollutants to be distributed in a log-normal fashion has also been noted in air and water pollution problems). Statistical distributions of some traffic noise levels are shown in Fig. 10. The quality L_n is the *n*th percentile value of the cumulated variable, the value that is exceeded *n* percent of the time. Equation 1 shows that wide variations in sound levels will increase the value of L_{NP}.

As mentioned earlier, propagation effects will cause differing changes in these various statistics as the observer (or source) moves from one place to another. Most studies of acoustical propagation have been concerned with changes in average signal energy only. In a traffic noise situation, we might want to determine the effect of a barrier, say, on the 10 percentile noise level (L_{10}), which may be quite different from its effect on L_{50}. Generally, a barrier has a greater noise-reducing effect on nearer sources than more distant ones. Since there are more sources at a distance, the effect of the barrier is to reduce the variance of the sound levels and to decrease L_{10} values more than L_{50} values are reduced (*32*). Similar calculations have also been made for sound transmission through walls and windows (*33*).

Delaney *et al.* (*29*) have shown that a row of houses facing a busy street will reduce the noise entering their

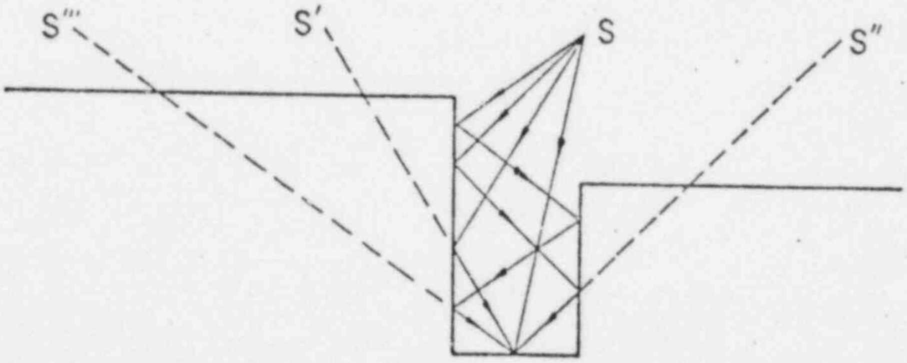


Fig. 12. Scale drawing showing acoustical images heard by listener. The sound generated at *S* is preserved at ground level on a simulated city street. The points *S'*, *S''*, and *S'''* are acoustical images of the source point.

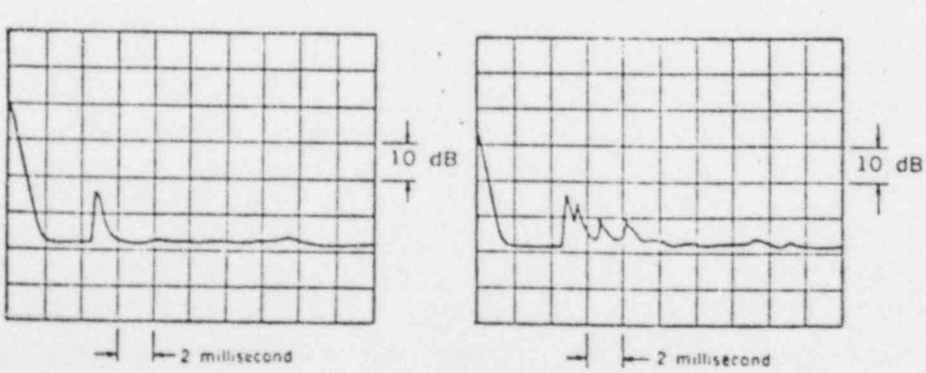


Fig. 13. Time pattern for received sound level in the 32-kilohertz band; (A) with sound absorbing material on the walls; (B) no sound absorbing material.

back yards by 10 to 15 dB. The noise reduction for the 10 percentile levels is about 5 dB more than it is for the 90 percentile levels. This would appear to confirm the suggestion that nearby sources (that are more effectively blocked by the houses) are responsible for the 10 percentile levels and that more distant sources dominate the 90 percentile levels.

If a particular kind of noise source is prevalent (such as surface vehicular traffic) these various statistics of the noise will be interrelated in the sense that the form of the distribution is known. Examples of traffic noise distributions in city streets are shown in Fig. 10 (*34*). In this event, one may represent the sound field by a single statistic, such as the L_{10} value. The English use L_{10} because it is not so dependent on infrequent, very loud noises in the way that L_1 or L_5 might be, and tends to be determined by noise sources that are generally in the vicinity of the observation point. Thus, one can avoid setting noise standards on the basis of the general prevailing background noise of the city in the way that L_{50} prescription might tend to do.

How Well Do We Understand Propagation?

In my discussion of what propagation effects are, and how we should use propagation information to predict noise measures of interest, I have only suggested some of the limitations that exist in predicting the numerical effect of propagation in particular situations. I will now discuss in more detail the problems of identification of propagation effects and the evaluation of those effects.

The first problem, that of identification, is the most crucial one. Practical field measurements rarely allow the kind of control of source parameters and variation in path properties that would be ideal. Thus, although we know that geometric spreading, reflection, and scattering are the important processes occurring in Fig. 9, for example, we cannot tell from the data just what the contribution of each will be. The data of Delaney *et al.* that apply to this situation are shown in Fig. 11 (*29*). As explained earlier, these data cannot be explained on the basis of reflection and geometric spreading alone.

One way of identifying propagation paths and effects is through the use of scaled models. In acoustic scaling, we select the frequency of operation so that the ratio of wavelength to dimension is preserved. If the modeling medium is air at ordinary temperatures, this means that high frequencies must be used. Typically, scaling ratios from 1 : 10 to 1 : 100 may be employed for propagation modeling, which may require that one generate and sense sound signals at frequencies up to about 200 khz.

An example of path identification by modeling is shown in Figs. 12 and 13 (*35*). In this experiment, a spark is used to generate an impulsive sound and the sound is measured at the ground in a model of a city street. The relative contribution of the reflections from building surfaces is determined by covering them with absorbing material. When this is done, only the direct pulse is evident at the microphone.

This experiment is a relatively simple example of an important advantage provided by the use of models. Changes may be made in the propagation path, walls may be made absorbent, rough, or of different shape, for example, in ways that could not be done in a field experiment. The field experiment is necessary as a baseline, however, and is used as a guide to establish realism in the model. Once the sound patterns in the model and the field data are found to correspond, variations in the surfaces, source, and receiver locations can be made. By changing from smooth building surfaces, for example, we can see the effects of surface scattering without changing other acoustical parameters such as path length or surface materials.

The phenomena associated with propagation can be discerned from laboratory or field data on the basis of time or spatial patterns of the sound. The quantitative prediction of the effect of each process may not be so quickly obtained. For example, the theory of surface scattering that has been so well developed for underwater sound (nonspecular reflection from the upper free surface and the bottom) has not been developed for the nonspecular reflection from the faces of buildings, or reflection from an irregular ground. In fact, most of the ordinary processes of sound propagation in the outdoors have obviously not had the degree of theoretical or experimental effort devoted to them that the more defense-related problems have.

Conclusions

Although the basic processes associated with the propagation of environmental noise, such as reflection, scattering, and spreading are well known, numerous theoretical problems remain. The propagation processes that are significant in different situations have yet to be identified, and criteria for evaluating their relative importance in each situation must be developed. In evaluating the noise of aircraft, for example, attenuation caused by the spreading of energy may exceed 60 dB, with atmospheric attenuation accounting for another 10 dB or so. In the propagation of highway noise, on the other hand, spreading may account for only 10 dB of attenuation, air absorption for 1 dB, and absorption by ground may account for 10 to 15 dB of attenuation. If those problems are approached systematically, we should be able to predict accurately the effects of noise sources and barriers and thus control the distribution of noise levels in cities and suburban areas.

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Here is a procedure for estimating the attenuation of sound outdoors near the ground in excess of inverse-square law spreading loss.

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Sound Propagation Outdoors

THE engineer is very often faced with the problem of estimating the sound-pressure levels generated by a source of sound some distance away. The roar of jet aircraft being run up on the ground wakes children from their sleep in an apartment house a mile or two away. Or an airplane taking off from a city airport interrupts telephone conversations in an office building under its climb path. In providing a sensible solution to these and a host of other problems of noise control, the engineer must take into account the attenuation of sound as it travels through the atmosphere. To be sure, in many cases the issue can be dodged by assuming "inverse-square law" attenuation and nothing more. This solution is almost always too conservative, i.e., the actual attenuation of sound that has travelled from source to receiver is larger than that calculated from the inverse-square law alone. In a growing number of cases, however, the engineer cannot afford to take the easy way out: a more accurate estimate of the actual atmospheric attenuation may result in a substantial saving in expensive noise control measures. This article attempts to provide a better understanding of the principles governing propagation of an acoustic signal in the audio frequency range through the lower atmosphere.* It also presents design charts based on recent measurements † which permit engineering estimates of the attenuation for a number of practical situations. The reader is cautioned, however, in two respects: there is, as yet, no comprehensive theory, and the body of available experimental data on which the design charts are based is still limited.

Sound Transmission Through the Lower Atmosphere

The atmosphere is by its nature in constant motion and fluctuation. Density, temperature, pressure, and humidity are never uniform in a given volume of air, nor are they constant in time. Sound waves travelling through the atmosphere show these nonuniformities by fluctuations in sound level, whose average value depends materially on the wind, temperature and humidity conditions along the path of propagation. The longer the transmission path through the atmosphere, the more important is the effect of these factors on the received sound level.

Typically, in a noise control problem, the receiving point is near the ground, and very frequently the noise source is also near the ground. The discussion in this article is, therefore, concerned primarily with the propagation of sound in the audible frequency range through the lower atmosphere along the ground, except in the important case of aircraft in low flight at an altitude of no more than a thousand feet or two. Sound transmission from aircraft flying at significantly higher altitudes will not be discussed here.

The strong interdependence between sound transmission along the ground and the "weather" is a matter of everyday knowledge. It has been a matter of scientific investigation for centuries.[1] Results were frequently not general enough or not of the type needed by the engineer until recently when adequate micrometeorological techniques became available and were brought to bear on the problem. Significant strides have been made toward an engineering

* Much of the material presented here has been taken from "Noise Reduction, A Series of Lectures Presented at the Massachusetts Institute of Technology," ed. Beranek (to be published by McGraw-Hill Book Co., Inc., New York).

† This work was carried out under contract with the U. S. Army Signal Corps.

solution to the problem by means of a combination of theory and empirical design curves. For air-to-ground transmission of the type [illegible] ed here, on the other hand, t[illegible] "weather" seems to play a much smaller role.[2] The material presented here is an attempt to reduce to engineering practice what has been learned from theory and experiment to date.

The Inverse Square Law and Excess Attenuation

In an ideal, homogeneous, lossfree atmosphere, the sound pressure decreases inversely with distance when one is in the far free field of the source. In other words, there is a 6-db decrease in sound-pressure level for each doubling of distance. However, due to atmospheric conditions and obstacles, the sound-pressure levels measured outdoors are almost always lower, sometimes drastically so, than those predicted from this spherical spreading alone. The important factors which affect sound propagation along the ground are: (1) [illegible]d absorption in the air; (2) [illegible]esence of walls and trees; and (3) wind and temperature gradients, atmospheric turbulence, and the acoustical effect of the presence of the ground.[1,3] All these factors are to some extent interrelated; the effect of one is dependent on the presence of the others. In the case of sound propagation from air to ground, the effect of obstacles on the ground and the effects of ground-created wind and temperature gradients are clearly not present. Sound absorption in the air and, to some extent, atmospheric turbulence are then the factors which primarily determine the attenuation.

It is useful to lump the net effect of atmospheric and terrain factors into a single quantity, the *excess attenuation* A_e in decibels over and above the effect of spherical spreading. For the purpose of arriving at an engineering estimate the excess attenuation can be split to several contributions assumed to be independent of each other:

$$A_e = A_{e1} + A_{e2} + A_{e3} \text{ decibels} \quad (1)$$

where:

A_e = total excess attenuation,
A_{e1} = attenuation due to absorption in the air,
A_{e2} = attenuation due to walls and trees,
A_{e3} = attenuation due to wind and temperature gradients, atmospheric turbulence and ground effect.

In the following, we shall discuss these various contributions quantitatively and from a practical point of view. They are evaluated primarily in terms of their average values, ignoring for the moment fluctuations in the received sound-pressure levels. It is assumed that the small-signal approximations hold and that the sound is not so intense that nonlinear terms need be considered.

The matter of sound absorption in the air, A_{e1}, while still a subject of investigation by several groups, is summarized in the literature[4] and will, therefore, not be discussed here in detail. Figure 1 shows an estimate of the attenuation due to sound absorption in the air plotted as a function of distance from the source for the various octave bands. These curves were derived by following an approximate procedure given in Reference 4. They represent a conservative (i.e., the predicted attenuation is smaller than that which one would measure) estimate of the actual values of molecular absorption. The curves will be useful in noise control problems until more accurate data become available. It was assumed, among other things, that the attenuation measured at the geometric mean frequency of the octave band is representative of that for the whole band and that the absolute humidity of the air through which the sound propagates is not too low (at least about 7 to 8 grams of water per cubic meter). The effect of barriers on the attenuation of sound was the subject matter of a recent article in these pages.[5] Those results can be used to evaluate the second term in the excess attenuation, A_{e2}.

In view of the above, a discussion of the effects of wind and temperature gradients, atmospheric turbulence, and the acoustical effect of the presence of the ground constitute the main part of this article.

Ground-to-Ground Transmission

Over open level ground, there are almost always appreciable vertical temperature and wind gradients; the former are due to the heat exchange between the ground

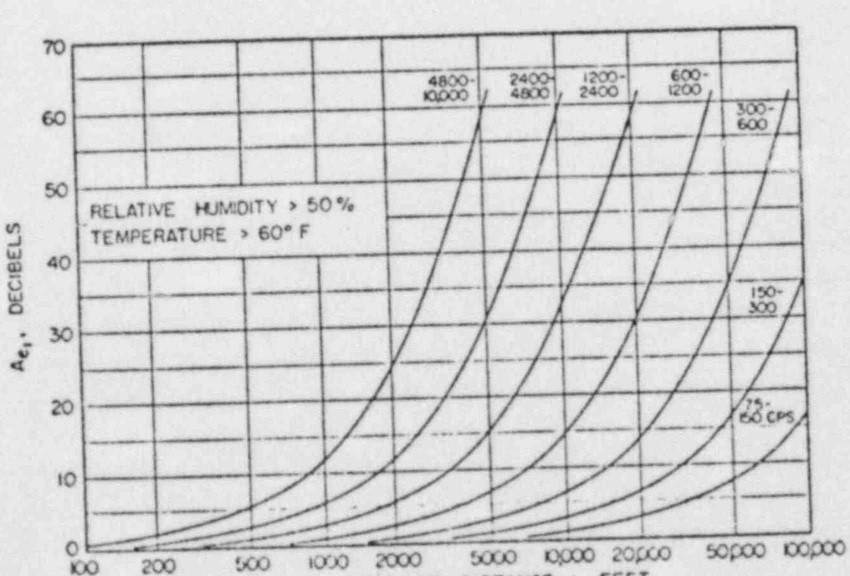
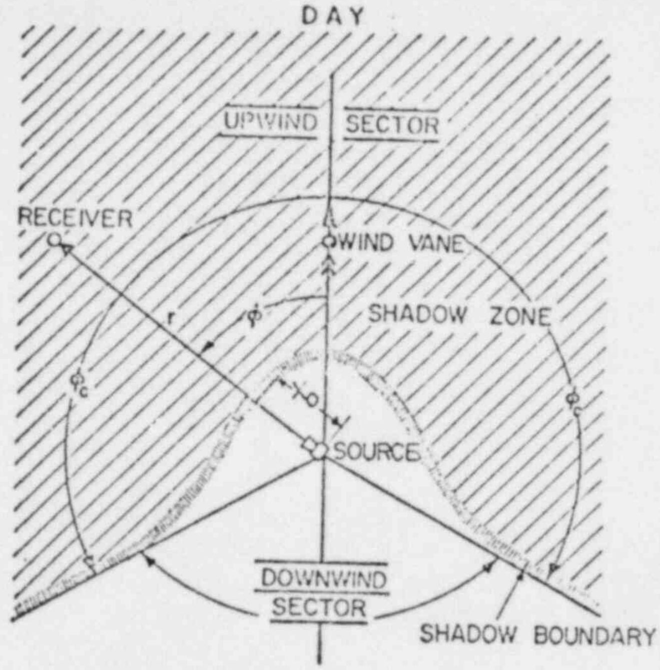


FIG. 1. Chart for estimating the excess attenuation of sound due to air absorption.

Fig. 2. Geometry of sound propagation over open level terrain (plan view) for typical day and night conditions.



X_0 = Distance from source to shadow zone

ϕ = Angle between wind and sound

ϕ_c = Critical angle

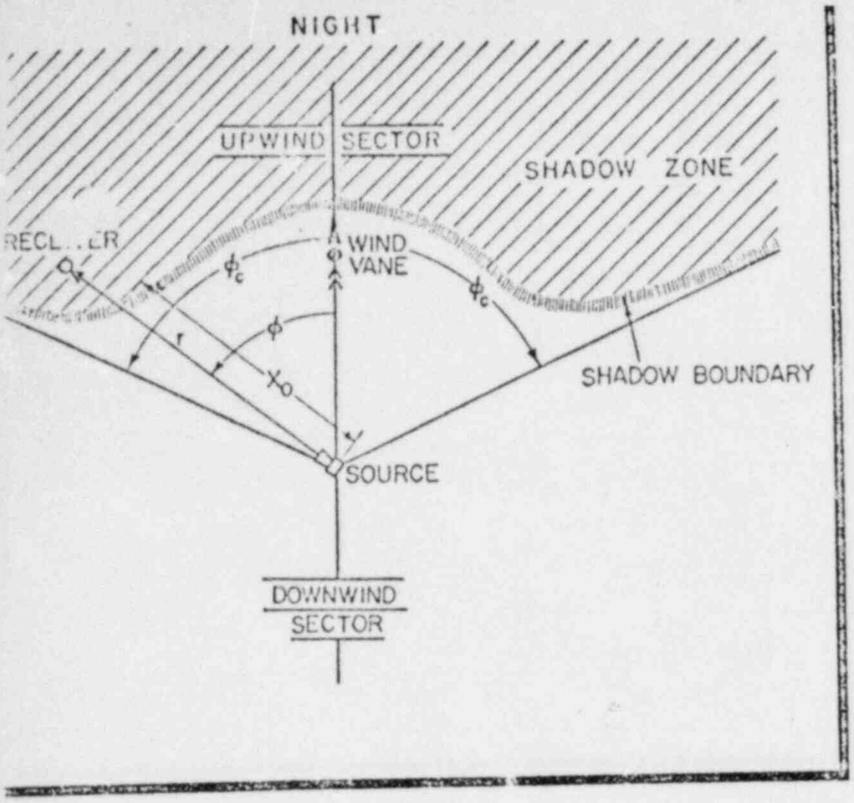
and the atmosphere, the latter, to the friction between the moving air and the ground.[6] Because of these gradients, the speed of sound varies with height above the ground and sound waves are refracted, that is to say, bent upward or downward. Under such conditions, it is possible to have a "shadow zone" into which no direct sound can penetrate. A shadow zone is most commonly encountered upwind from a source, where the wind gradient bends the sound rays upward.* Downwind, the wind gradient bends the sound rays downward and generally no shadow zone is produced. Thus, the refraction of the sound waves by wind is not symmetrical about the source. The refraction of sound waves by temperature gradients, on the other hand, is symmetrical about the source. Typical daytime conditions are a negative temperature gradient or *temperature lapse*, i.e., the air temperature decreases with height. Sound waves are then refracted upward, and if the wind speed is low, a shadow zone may encircle the source completely. At night, with low winds and clear sky, a positive temperature gradient, or *temperature inversion*, exists and the sound rays are refracted toward the ground. With wind present, wind and temperature effects superimpose, but usually the wind effects control.

These shadow zones are never sharp in the sense of light propagation. Sound energy is diffracted into the shadow zone as well as scattered into it by turbulence.[7] Some investigators feel that the finite acoustic impedance of the ground affects the sound-pressure level along the ground both in and outside of the shadow zone. Few systematic data are available for an estimate of this type of acoustical ground effect. However, the presence of the ground makes itself most strongly felt by creating wind and temperature gradients rather than by its finite acoustic impedance.

In the present state of the art it seems best to take an experimental approach to the problem of providing engineering estimates for the excess attenuation due to weather effects. Not only is there no comprehensive theory, but neither the measurement nor estimation of the micrometeorological parameters (which of necessity must be used in any computation of the excess attenuation) is probably not practical for the average engineer interested in noise control. On the other hand, useful engineering estimates of the excess attenuation to be expected from temperature and wind gradients over open level terrain can be obtained by considering recent experimental data.

Figure 2 shows typical day and night situations. Source and receiver are shown a distance r apart. The average direction from which the wind is blowing is indicated by a wind vane. The angle between the direction of the wind vane and the line connecting the source and receiver is called ϕ. There is generally a shadow zone (the shaded regions of Fig. 2) on the upwind side of the source because sound waves travelling upwind tend to be bent upward by the wind. However, any wind present tends to bend the sound waves downward in the downwind direction, and there is no shadow zone there. During the day the negative

* Wind gradients near the ground are, on the average, always positive, i.e., the wind speed increases with height.



...mperature gradient tends to reinforce the shadow zone formation upwind but to oppose it downwind. At some critical angle ϕ_c the wind and temperature gradients cancel each other and the distance to the shadow zone recedes theoretically to infinity. As a result the plane is divided into an upwind sector $2\phi_c$ and a downwind sector $360° - 2\phi_c$. At night the critical angle ϕ_c is typically much smaller than during the day. With very light winds and a strong temperature inversion, no shadow zone exists and the critical angle is zero.

Experiments have shown that the excess attenuation is frequently radically different upwind and downwind, with a gradual transition at the boundaries $\phi = \pm\phi_c$. On a sunny day with moderate winds, the excess attenuation inside the shadow zone upwind is typically 20 to 30 db higher than that for the same distance downwind.

Extensive measurements in the frequency range from about 300 to 5000 cps have been made recently under a large variety of micrometeorological conditions.[8] These measurements have been taken over open level terrain with sparse low ground cover (1 to 2 ft high), a source height of 12 ft and a receiver height of 5 ft. Windspeeds encountered ranged from 2 to 3 mph to 10 to 15 mph. From this series of experiments empirical design curves have been derived,[9] with the aid of which the excess attenuation can be estimated for any angle ϕ, and for distances r up to about one mile, provided the temperature and wind gradients are known at a height of approximately half the average source and receiver heights. Since the experiments did not include tests at the very low and very high audio frequencies, the design curves are subject to confirmation there.

In a typical noise control situation, the problem is usually not that of estimating the excess attenuation A_{e3} for a given instant, but of estimating A_{e3} on a year-round

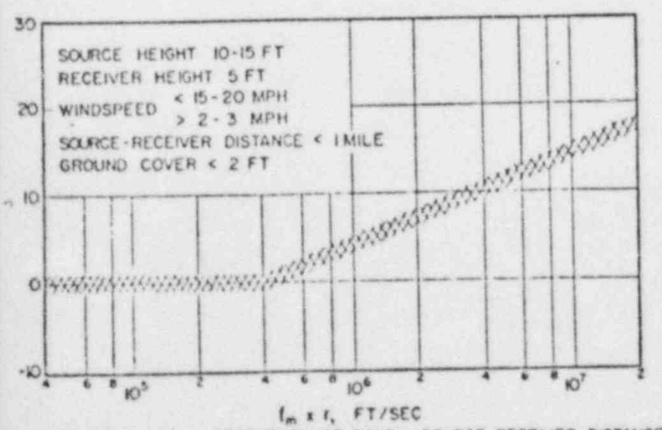


Fig. 3. Chart for estimating the excess attenuation of sound prop... downwind over open level terrain (subject to confirma...n at the very low and very high audio frequencies).

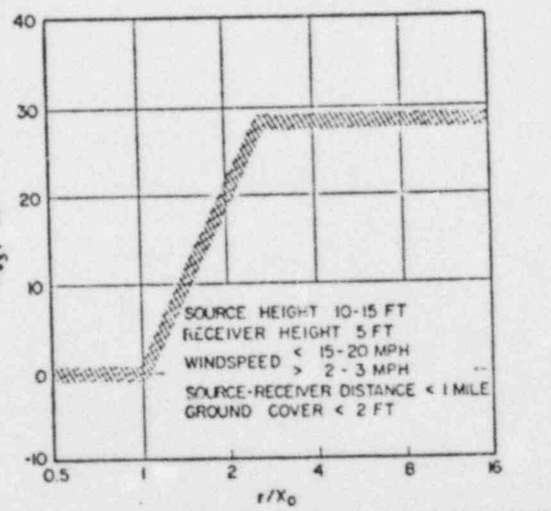


Fig. 4. Chart for estimating the excess attenuation of sound propagated upwind over open level terrain (subject to confirmation at the very low and very high audio frequencies).

basis perhaps, or for many values of ϕ, since the wind direction is generally subject to diurnal and seasonal changes. Diurnal and seasonal variations occur also in the temperature and wind gradients. In view of the complexity of the problem it seems best to restrict ourselves to two conditions: (1) straight downwind propagation ($\phi = 180°$), and (2) straight upwind propagation ($\phi = 0°$). These conditions bracket the extreme values of A_{e3} for any given set of conditions. The engineer must then make his choice appropriate to the problem at hand.

Figure 3 is the empirical design chart giving values of A_{e3} for straight downwind propagation. The abscissa is plotted in terms of the product $f_m \times r$, where r is the distance from the source to the receiver in feet, and f_m is the center frequency of the octave band in question, in cycles per second.

Figure 4 is the design chart giving values of A_{e3} for straight upwind propagation. The abscissa is plotted in terms of source-receiver distance, normalized to the distance X_0 from the source to the shadow zone. The distance X_0 can be obtained by simple measurements in the field, since at that distance the sound-pressure level starts to drop markedly below what would be expected from the inverse-square law. The drop can often be detected by ear. For the given heights of source and receiver, the distance X_0 can also be estimated from the values given in the table.

It should be noted that these design charts contain implicitly the effect of atmospheric turbulence near the ground on the received sound-pressure level. Work is in progress to determine the effect of atmospheric turbulence itself as distinct from other effects. Although preliminary results indicate that the attenuation due to turbulence, in decibels, depends linearly on distance, it is still too early to draw more general conclusions.

Air-to-Ground Transmission

This case is of considerable practical importance for the engineer who needs to estimate the sound-pressure level near the ground due to aircraft overhead. For sources at moderate altitudes, say, 1/2 mile or less, experiments have shown that the excess attenuation can be attributed primarily to molecular absorption and atmospheric turbulence. Until more accurate data are available on the excess attenuation due to turbulence, it seems best to take only molecular absorption into account (Fig. 1). These calculations are to be regarded as an estimate at best, since it is difficult to infer the average atmospheric conditions along the transmission path from measurements of the state of the atmosphere at ground level.

As the aircraft passes overhead in level flight, the sound-pressure level at a fixed point on the ground will rise, go through a maximum, and fall again. The position of the aircraft for maximum sound-pressure level depends on its acoustic directivity pattern. As a first approximation, a 45-degree position can be assumed for jet aircraft. Consequently, this slant distance is the effective length of the transmission path and must be used not only to compute the excess attenuation but also the spherical divergence. For propeller aircraft the minimum distance to the flight path should be used.

Fluctuations of the Received Sound-Pressure Level

Fluctuations in level are characteristic of sound that has travelled through the atmosphere. These fluctuations typically encompass a fairly wide frequency spectrum and peak-to-peak fluctuations of appreciable magnitude occur. The peak-to-peak fluctuations for sound propagated over level ground have been investigated.[5] The following general conclusions can be drawn and are essentially substantiated by the findings of other investigators: (1) for downwind propagation, the magnitude of the fluctuations increases with the frequency of the signal and with distance, (2) for upwind propagation the magnitude of the fluctuations is greatest near the shadow boundary, (3) in a stable atmosphere (clear night, weak winds) the peak-to-peak fluctuations are typically about 5 db, (4) in an unstable atmosphere (clear sunny day, strong winds) the peak-to-peak fluctuations are typically 15 to 20 db, (5) the spectrum of the fluctuations measured over open level ground has components from fractions of a cycle to several cycles per second, (6) sound propagation from air to ground is frequently characterized by large low-frequency fluctuations in the received sound-pressure level in addition to the faster fluctuations observed over level terrain.

Estimates of Distance X_0 Upwind

Source height: 10–15 ft; receiver height: 5 ft

Day	Night	Sky: Clear	Sky: Overcast	Temp. Profile: Lapse	Temp. Profile: Neutral	Temp. Profile: Inversion	Wind mph	X_0 ft
	x	x				x	2–4	2000
x			x		x		10–15	400
		x		x			10–18	250

Conclusions

Progress has been made recently in furnishing the engineer with a better estimate of the attenuation of sound propagated outdoors than that provided by the inverse-square law alone. Future refinements will require not only the results of further basic research and experimentation but also the willingness and ability to use appropriate micro-

(Continued on page 55)

TABLE 47

CONVERSION TERM, INCLUDING ABSORPTION LOSSES, FOR CALCULATING SPL FOR DISTANCES OF 100 FT. TO 10,000 FT. FROM A NOISE SOURCE OF POWER PWL

SPL = PWL - CONVERSION TERM

where PWL is in dB re 10^{-12} watts

DISTANCE D (ft)	CONVERSION TERM (TO NEAREST dB) FOR OCTAVE FREQUENCY BAND (cps) 31-250	500	1000	2000	4000	8000
100	38	38	38	38	39	39
112	39	39	39	39	40	41
126	40	40	40	40	41	42
141	41	41	41	41	42	43
158	42	42	42	42	43	44
178	43	43	43	44	44	46
200	44	44	44	45	46	47
224	45	45	45	46	47	48
252	46	46	46	47	48	50
282	47	47	47	48	49	51
316	48	48	48	49	50	53
356	49	49	49	50	52	54
400	50	50	51	51	53	56
448	51	51	52	52	54	57
504	52	52	53	54	56	59
564	53	53	54	55	57	61
632	54	54	55	56	59	63
712	55	56	56	57	60	65
800	56	57	57	58	62	67
900	57	58	58	60	64	70

TABLE 47 (continued)

DISTANCE D (ft)	CONVERSION TERM (TO NEAREST dB) FOR OCTAVE FREQUENCY BAND (cps) 31-250	500	1000	2000	4000	8000
1000	58	59	59	61	66	72
1120	59	60	61	62	68	75
1260	60	61	62	64	70	78
1410	61	62	63	65	73	81
1580	62	63	64	67	75	85
1780	63	64	66	68	77	89
2000	64	65	67	70	79	93
2240	65	67	68	72	82	97
2520	66	68	70	74	85	102
2820	67	69	71	75	89	108
3160	68	70	72	77	92	114
3560	69	72	74	80	96	120
4000	70	73	76	82	101	128
4480	71	74	77	84	105	136
5040	72	76	79	87	111	145
5640	73	77	81	90	116	154
6320	74	78	83	93	123	165
7120	75	80	85	96	130	178
8000	76	82	87	100	138	191
9000	77	83	90	104	146	207
10000	78	85	92	108	155	222

C. E. Hickman
E&D - SCS
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VEGP-OLSER-Q

Question E290.14:
Provide the transmission line noise study prepared by Southern Company Services for the Miller-Arkadelphia 500 kV line.

Response:
A ~~One~~ copy of ~~the~~ this report ~~requested in enclosed.~~ was provided by D. O. Foster's letter to H. R. Denton dated May 25, 1984

SOUND LEVEL STUDY

MILLER-ARKADELPHIA 500 kV TRANSMISSION LINE

ALABAMA POWER COMPANY

Marvin T. Newton

Charles E. Hickman

Jack H. Eastis

Research & Development Department
Southern Company Services, Inc.
Birmingham, Alabama

August 16, 1978

INTRODUCTION

Due to the concern of the local citizens of Blount, Walker, and Jefferson Counties, Alabama, and in the customer interest of Alabama Power Company, a complete sound level survey to determine noise associated with the high voltage (500 kV) transmission line interconnect between Miller Steam Plant (APCo) and Tennessee Valley Authority (TVA) was requested by Alabama Power Company.

The survey was conducted by the Research & Development Department of Southern Company Services, Inc., of Birmingham, Alabama.

One major concern seemed to be the noise emitted from the line in relation to adverse weather conditions, i.e., rain and damp conditions. Therefore, it was decided that a test site should be chosen at which a continually operating test station (mobile trailer) could be installed. This test station was equipped to provide the following parameters:

- "A" weighted sound level
- Rainfall
- Wind speed
- Wind direction
- Ambient temperature
- Dewpoint

On January 4, 1977, the test station was moved to the site which was located under the transmission line in an open pasture in Blount County, Alabama. Although the time frame of the study spanned one of the worst droughts in Alabama history, a number of adverse weather condition periods allowed the accumulation of considerable data.

INSTRUMENTATION

On February 4, 1977, test equipment was installed and made operational. A list of test equipment follows:

Sound Level Monitoring System

System 1:

B&K Type 4920 Outdoor Microphone System
B&K Type 2120 Frequency Analyzer

System 2:

General Radio Type 1560-P6 Microphone
General Radio Type 1560-P40 Preamplifier
Power Mate (PMC) Model BP34D PowerSupply
B&K Type 2120 Frequency Analyzer

Weather Monitoring System

Weather Measure Type P501-1E Rain Gauge
Weather Measure Type P521-E Event Clock/Recorder
Climet Model 011-1 Wind Speed Transmitter
Climet Model 015-3 Ambient Temperature Sensor
Climet Model 015-12 Lithium Chloride Dewpoint Sensor
Climet Model 016-2 Asperated Temp. & Dewpoint Shield
Climet Model 060-10 Translator
TechEcology Model 020 Wind Direction Sensor & Adapter Card For Climet Translator

Due to internal oscillator and microphone problems, a second outdoor microphone system utilizing a General Radio Type 1560-P6 microphone and a General Radio Type 1560-P40 preamplifier in conjunction with the B&K Type 2120 analyzer was installed on February 24, 1977 to replace System 1. After experimentation as to the best locations for all sensors and the resolution of minor problems with sound level System 2, test data collection began on February 25, 1977.

Figure 1 shows the test site area and sensor locations. Figure 2 shows the location of the test site with respect to Structures 33 and 34 along the Miller-Arkadelphia transmission line and Figure 3 illustrates the configuration of the structures and conductor bundles.

During the course of the test period, equipment malfunctions proved to be of major concern. Although some causes remain unknown, the source of most failures or malfunctions could be determined. Lightning during storms took its toll on power supplies and preamplifiers. Also, during certain periods--particularly very dry periods--ground loop problems arose, and induced voltage signals made data unreliable. The data recorded during these equipment malfunctions have been omitted from the report.

Data which are deemed accurate have been tabulated on an hour-to-hour basis and are included at the end of this report as Table 2. This table includes not only sound level data but also meteorological data. Therefore, the reader has access to considerable data which may not be explicitly described in this report but which should be informative.

COMPONENTS OF TRANSMISSION LINE AUDIBLE NOISE

Audible noise from transmission lines is primarily a wet or damp weather phenomenon, i.e., during rain, fog, snow, icing, etc., the sound level may increase significantly from low ambient levels. During wet weather conditions, water droplets collecting on the conductors produce numerous corona discharges which generate random noise. During dry weather, the conductors usually operate below the corona-inception level. Two components of audible noise are normally associated with transmission lines; namely, (1) broadband, and (2) pure tones at frequencies of 120 Hz and multiples.

The broadband component is generated by corona where corona is defined as a luminous discharge due to ionization of the air surrounding a conductor caused by a voltage gradient exceeding a certain critical value. Since corona consists of a random sequence of pulses produced by the discharges, a broadband noise, described as a crackling or hissing sound, results.

The ionization of the air creates a space charge around the conductors and the movement of this space charge causes a reversal of air pressure twice every half-cycle which, in turn, generates the pure tone components. The pure tones, with the 120 Hz tone predominating, produce a sound described as a "hum." The hum component may vary over a wide sound level range with respect to both time and space. For example, the 120 Hz component may fluctuate several decibels with time at one location and will vary greatly over short lateral distances.

The two components may be quite evident simultaneously, or one or the other may predominate. Figures 4 and 5 illustrate sound level spectrums obtained during wet weather conditions at two different times. Note that in Figure 4 a broadband spectrum exists with little evidence of pure tones whereas in Figure 5 pure tones are quite evident.

For additional information, the reader is referred to a detailed discussion contained in Chapter 6, "Audible Noise," in the book Transmission Line Reference Book - 345 kV and Above published by the Electric Power Research Institute (EPRI).

ANNOYANCE OF TRANSMISSION LINE AUDIBLE NOISE

To determine annoyance associated with transmission line audible noise, both the broadband and pure tone sound level components must be considered. Most of the accepted community noise criterions introduce a penalty for the presence of pure tones in the received sound signal. At the present time, there are no sound level regulations which have been written specifically for transmission line audible noise. However, the Environmental Protection Agency (EPA) has published documents which rate the "normalized day-night sound level" as "probably the best available method at present to predict the most likely community reaction in the United States." There is a 5 dB penalty associated with a noise having tonal components using this criterion.

Also, State and local ordinances are being passed regularly with nighttime limits of 45-55 dBA. With no statewide noise regulations in effect in Alabama, complaints must be handled on an individual basis from a nuisance standpoint.

AUDIBLE INTERFERENCE AND NEGLIGIBLE NOISE SOURCES

It should be noted that during the test period, various other noise sources that were not associated with the subject transmission line contributed to the recorded data. For example, while reviewing Table 2, any data recorded while wind speeds were in excess of any average of 12 mph or more should be deleted since the speeds cause a corresponding increase in ambient noise level as illustrated by Figure 6.

Another example of "other" noise sources are, of course, the normal wildlife sounds which are very typical in the region of the subject transmission line. In this rural community, birds, frogs, and crickets were major sources of noise.

Note on the tabulated data that at approximately 1800 most evenings from about the middle of March until the end of the same month, there is an abrupt increase in sound level of approximately 15 dBA. This increase is due to crickets in the local area. The higher sound level generally held constant for a period of an hour or two and then decreased at sunset (Figure 7).

ADVERSE WEATHER OBSERVATIONS

To better grasp the idea of transmission line noise during "adverse weather," it must first be established what should be considered "normal" ambient conditions. For this purpose, March 29, 1977 has been chosen as an example using Figure 8a. (NOTE: The wind direction indicator was out of order during this period. However, this parameter is considered irrelevant to sound level at subject test site.)

At 0600 on the subject day, the following ambient conditions were present. The wind speed averaged 5 mph with ambient temperature at 16.5^{o}C and dewpoint at 15.0^{o}C. The load on the line was -3.9 MW. The sound level measured 50' east of the outer phase of transmission line was 42 dBA. Taking into consideration the season and time of day, these conditions are assumed to be "normal."

At 1600 hours, a steady rain was falling which had commenced at approximately 1410. At 1600, the wind speed was averaging 6 mph, temperature at 16.5^{o}C, dewpoint at 14.5^{o}C, and the load on the line was 17.2 MW. The noise level at 1600 had increased to an average of 55 dBA (Figure 8b). Since other ambient conditions were relatively constant, it is concluded that this sound level increase was, in fact, due to an excitation of the line corona by precipitation (rainfall).

Another example of this adverse weather phenomenon occurred on April 1, 1977. At approximately 1220, a light rain commenced. The wind was from the southeast at 8 mph. The ambient temperature was 14.0^{o}C; the line was +124.5 MW. Before the rainfall, the sound level under the center phase of the line was 38 dBA. When a light rain commenced, the sound level increased to 45 dBA. At this time, the line was emitting the light hissing sound. This hissing became louder until approximately 1230. At this time, the rain continued to fall harder and a 120 Hz hum was evident. This hum predominated the hissing noise, and as the rain continued to fall, the sound level increased to an average of 55 dBA with other ambient conditions remaining near constant. There is no recording of this particular example, but this phenomenon was observed and logged by project technicians present at the time.

Figures 4 and 5 may be used to illustrate these two components of line noise since the events which occurred on April 1, 1977 are almost identical to those events at the time the figures were recorded (July 29, 1977).

The examples described in this section are prime examples of the effects of adverse weather on the subject transmission line. Other examples of adverse weather conditions may be observed in Tables 1 and 2 and Figures 9-12 of this report.

CONCLUSIONS

At the test site utilized for the subject sound level study, it was found that the sound level on a "normal" day (clear with no precipitation) roughly averaged between 38 and 42 dBA with moderate to full line load. It should be noted that this average was derived using optimum conditions when no other major noise sources (i.e., crickets, excess winds, farming equipment) were present.

It was also found that during moderate to heavy rainfall with moderate to full load on the line and no other major noise sources present that the average sound level at the test site ranged from 55 to 58 dBA.

It is, therefore, concluded that adverse weather (i.e., rain) excites high voltage transmission line corona causing a 13 to 20 dBA increase in sound level.

To further examine these adverse weather effects, a sound level traverse (lateral noise profile) is planned to extend 500 feet from either side of the transmission line or until ambient sound level is achieved.

At the time of this writing, the profile has not been completed. Upon completion of the traverse, an appendix will be issued to this report.

TABLE 1

EXPLANATION OF FIGURES

Figure 1

The test trailer was located approximately 20' west of the west phase of transmission lines. The trailer was enclosed inside a 35' X 16' chain link fence with proper security and voltage warning signs.

Figure 2

This figure shows terrain and line configuration in the test site area. (NOTE: The various sag distances in the line are true for a $100^{o}C$ temperature at full line load conditions.)

Figure 3

This figure shows a typical tower configuration for the subject transmission lines and the typical conductor bundle arrangement for each phase.

Figure 4

A tape recording was made at the test site on July 29, 1977 during a steady rainfall. This figure illustrates the phenomenon that usually occurs during moderate load conditions with a light rain falling. The noise that was emitted from the line at this time was the aforementioned hissing type of sound. There is very little evidence of pure tone(s).

The sound level meter was placed on the 60 dBC scale while recording.

Figure 5

This figure was plotted from the same tape utilized for Figure 4. The sound level meter was placed on the 60 dBC scale.

Notice the obvious pure tones. This phenomenon usually occurred as the rain fell harder and the transmission line became wetter.

The noise emitted from the line was a distinct "hum" at 120 Hz.

The major peaks shown are as follows:

Frequency (Hz)	dBC
120.00	47.8
180.00	30.0
240.00	39.6
360.00	30.6
480.00	29.2

Figure 6

This figure shows the effects of excess wind on sound level. During the period of this recording (March 22, 1977), the wind was averaging $\sim$ 18 mph with gusts to 33 mph.

Figure 7

This figure is a chart recording of the "cricket phenomenon" which was recorded on March 23, 1977. This phenomenon was found to occur at approximately the same time each evening as warmer weather brought about more activity.

Figure 8a & 8b

Figure 8a shows the "normal" sound level average with no adverse weather conditions on March 29, 1977.

Figure 8b shows the effect of rainfall that occurred on the same day but several hours later. At approximately 1410, a light rain had commenced. By 1520, 0.11" of rain had fallen. The sound level before rainfall averaged 43 dBA. During the peak of rainfall, the sound level increased to an average of 55 dBA.

Figure 9

This figure shows the sound level during rainfall on June 16, 1977.

Note the broad peaks before and after the sound level increase. These peaks are due to wind which subsided during rainfall.

The average sound level one hour before rainfall was 43 dBA. The sound level increased to 55 dBA during peak of rainfall.

Figure 10

This figure shows sound level increase of 15 dBA during rainfall that occurred on September 6, 1977.

The average sound level before rainfall was 45 dBA. A steady rain commenced at $\sim$ 0910 and sound level abruptly increased to 58 dBA then settled to average 55 dBA during the peak of rainfall.

Figure 11

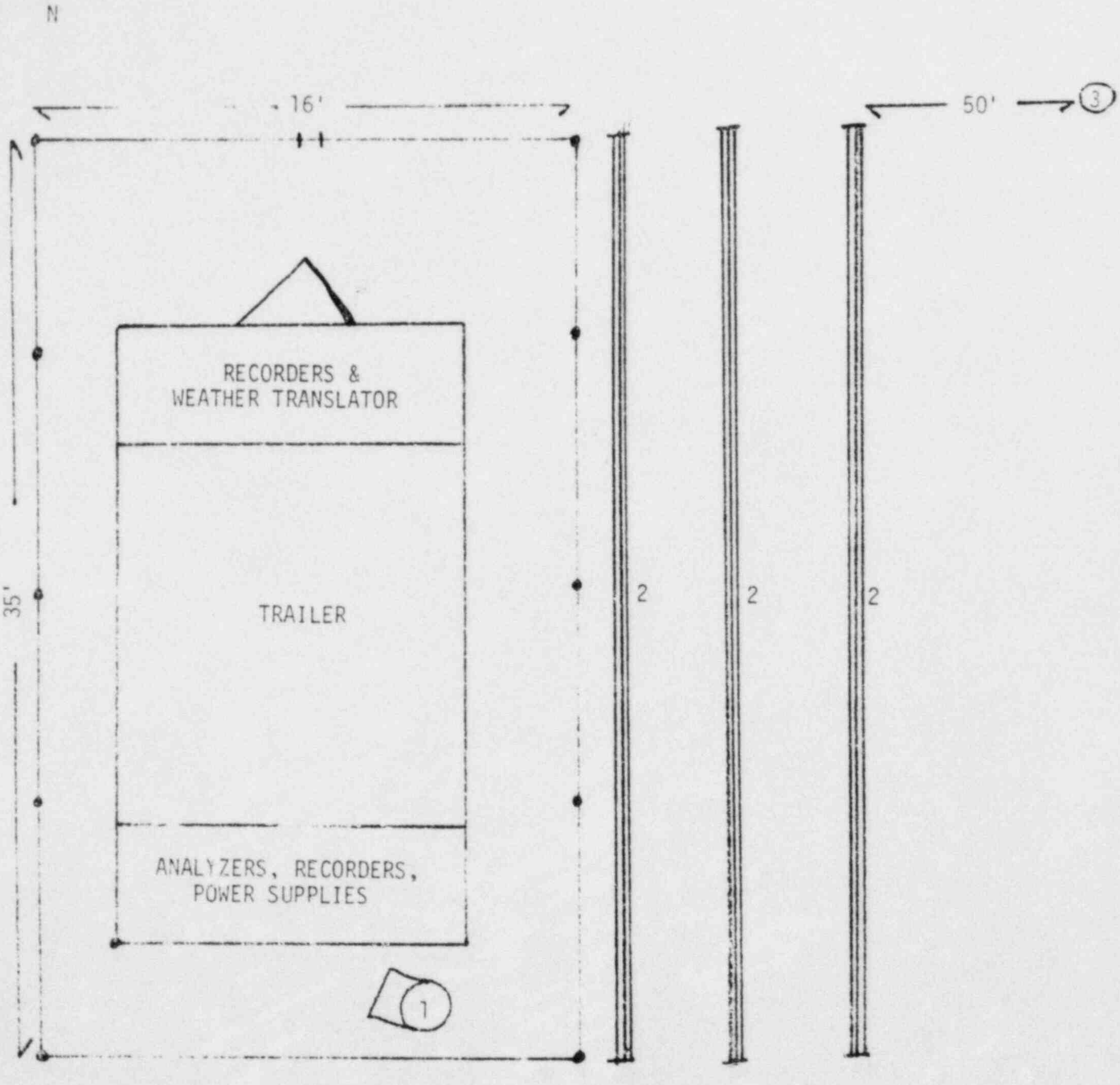
This figure shows the effect of rainfall that occurred on the morning of September 4, 1977. The rain commenced to fall at $\sim$ 0515 and had accumulated 0.05" by 0700.

The sound level increased from an average of 46 dBA before rainfall to 56 dBA during rainfall.

Figure 12

This figure shows the effect of rainfall which occurred at the test site on September 4, 1977.

There was a light rain falling at $\sim$ 1100 but not hard enough to create more than a hissing. At $\sim$ 1225, the rain commenced again with an abrupt increase in sound level.



1. Power pole with extended platform for rain gauge; all weather sensors mounted here.
2. Transmission lines
3. Outdoor microphone and preamp

Figure 1. Test Site Layout

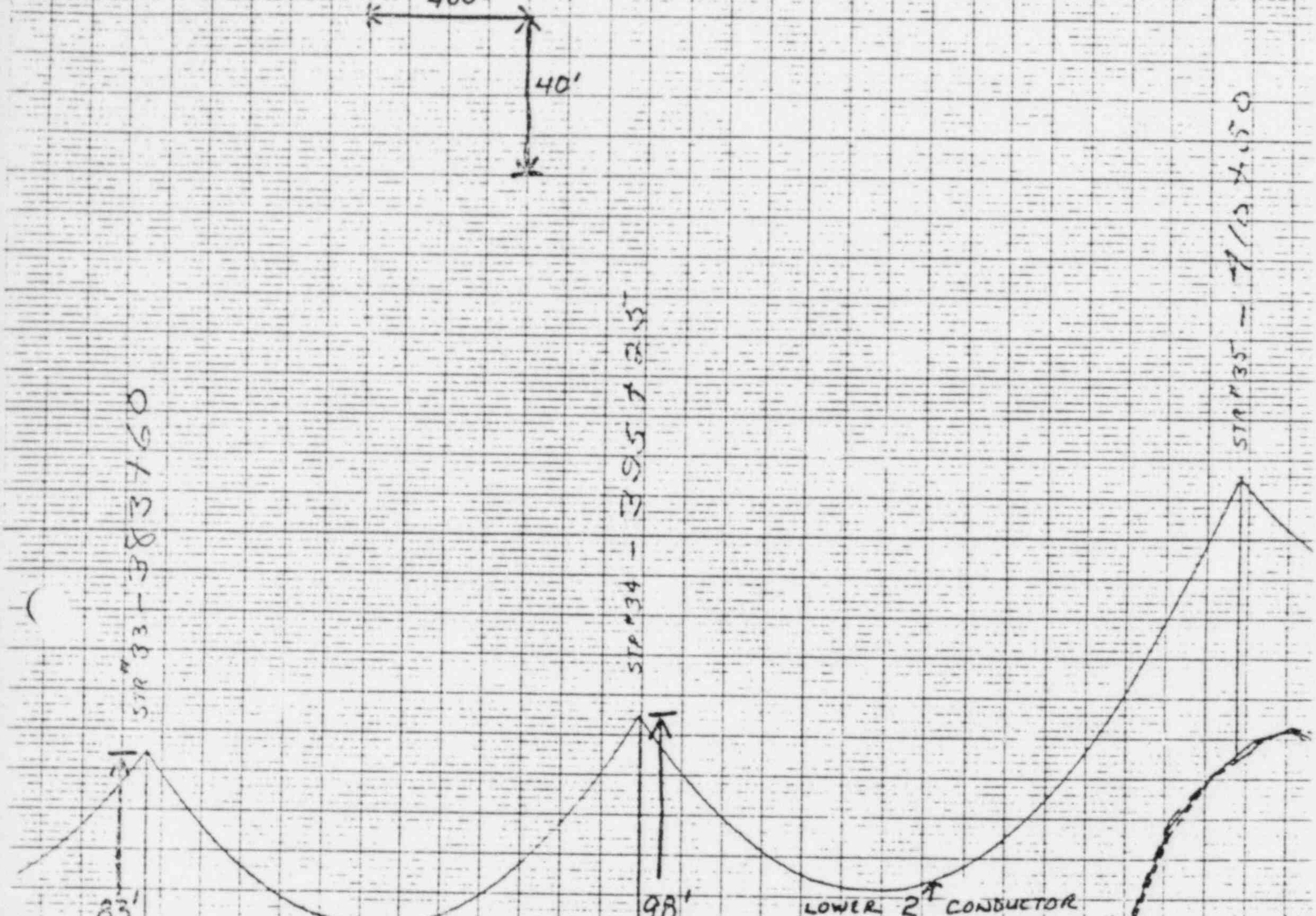


Figure 2. Location of test site with respect to Structures 33 and 34 along the Miller-Arkadelphia 500 kV transmission line.

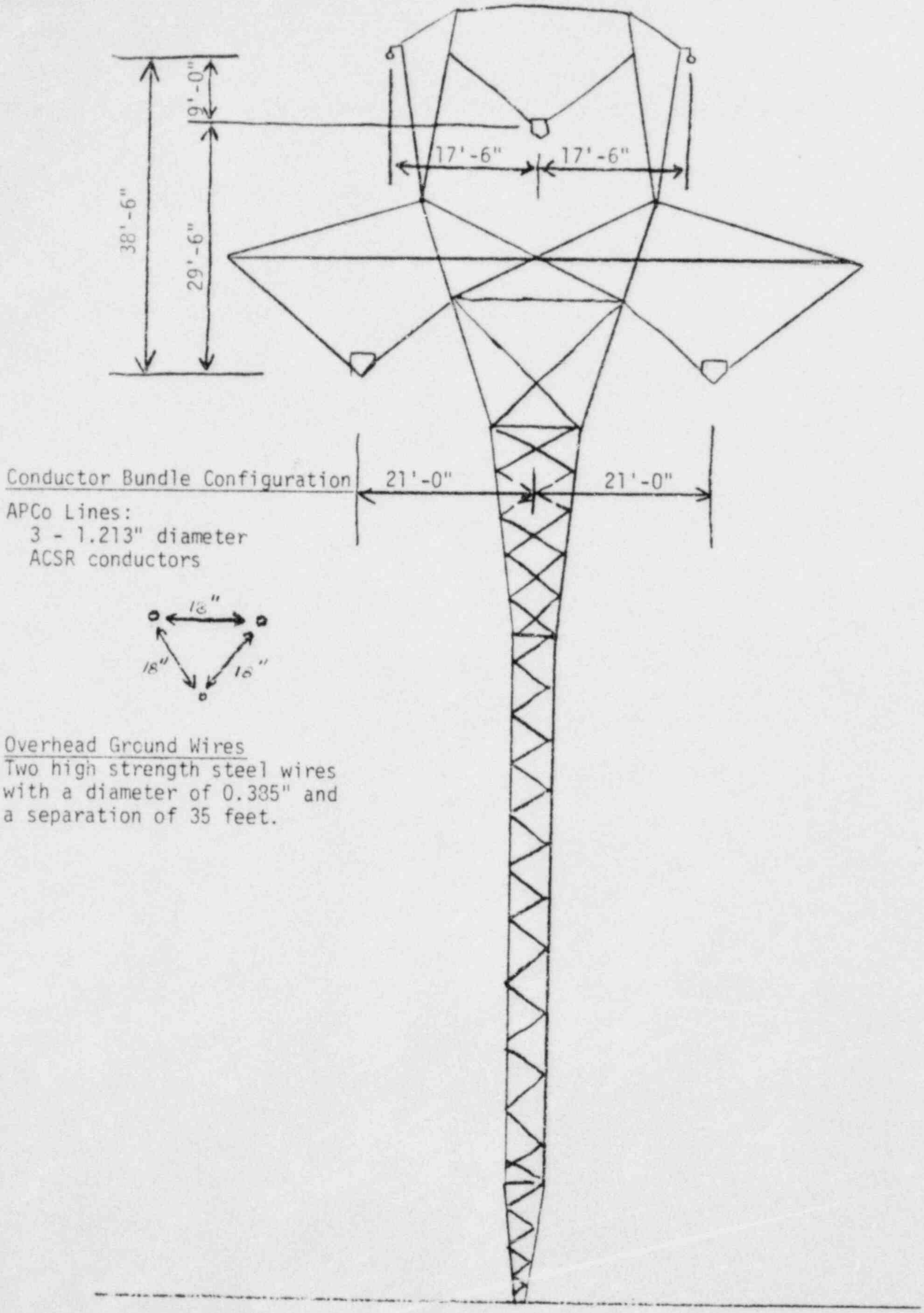
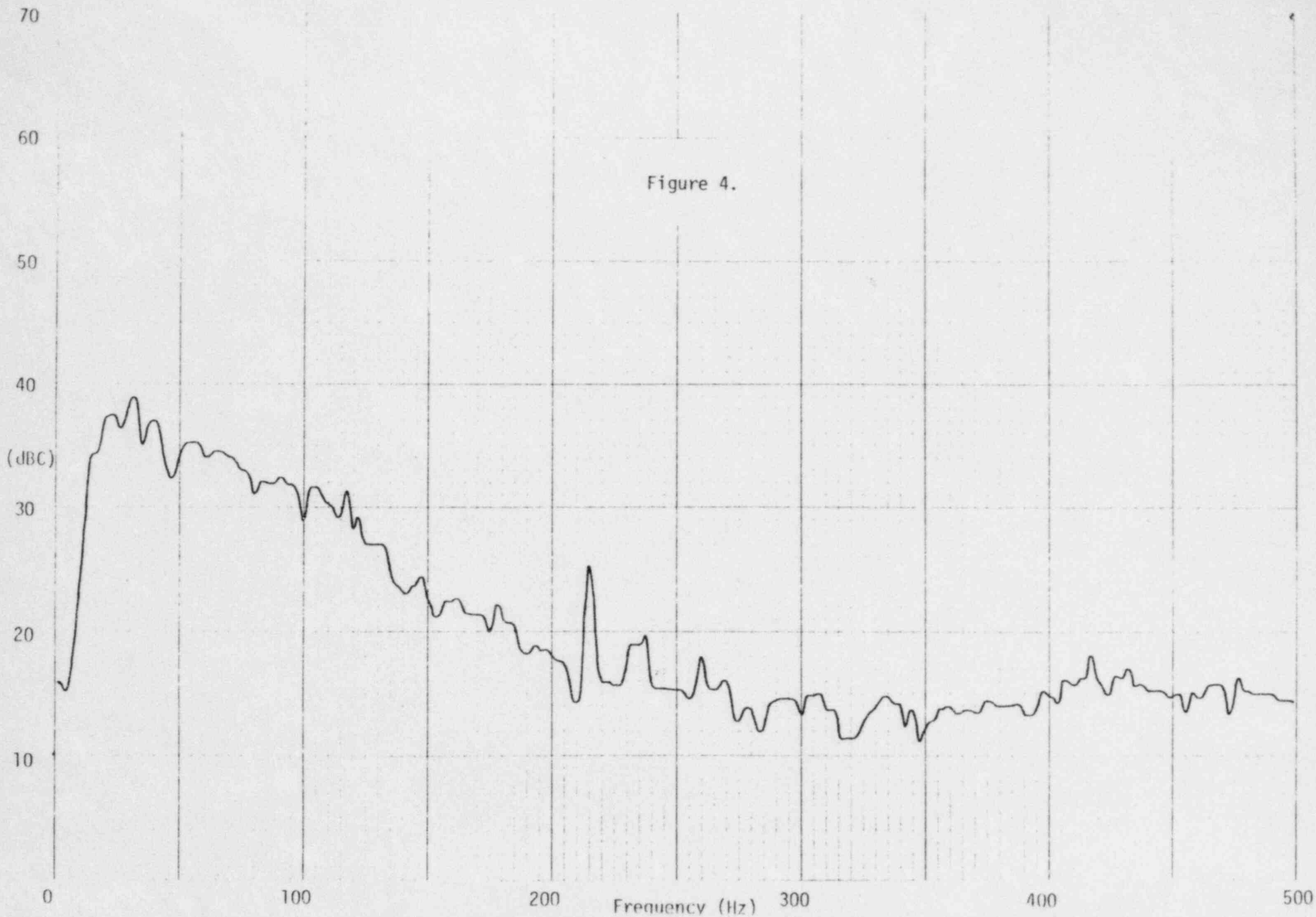


Figure 3. Transmission line structure and conductor bundle configurations.

Figure 4.



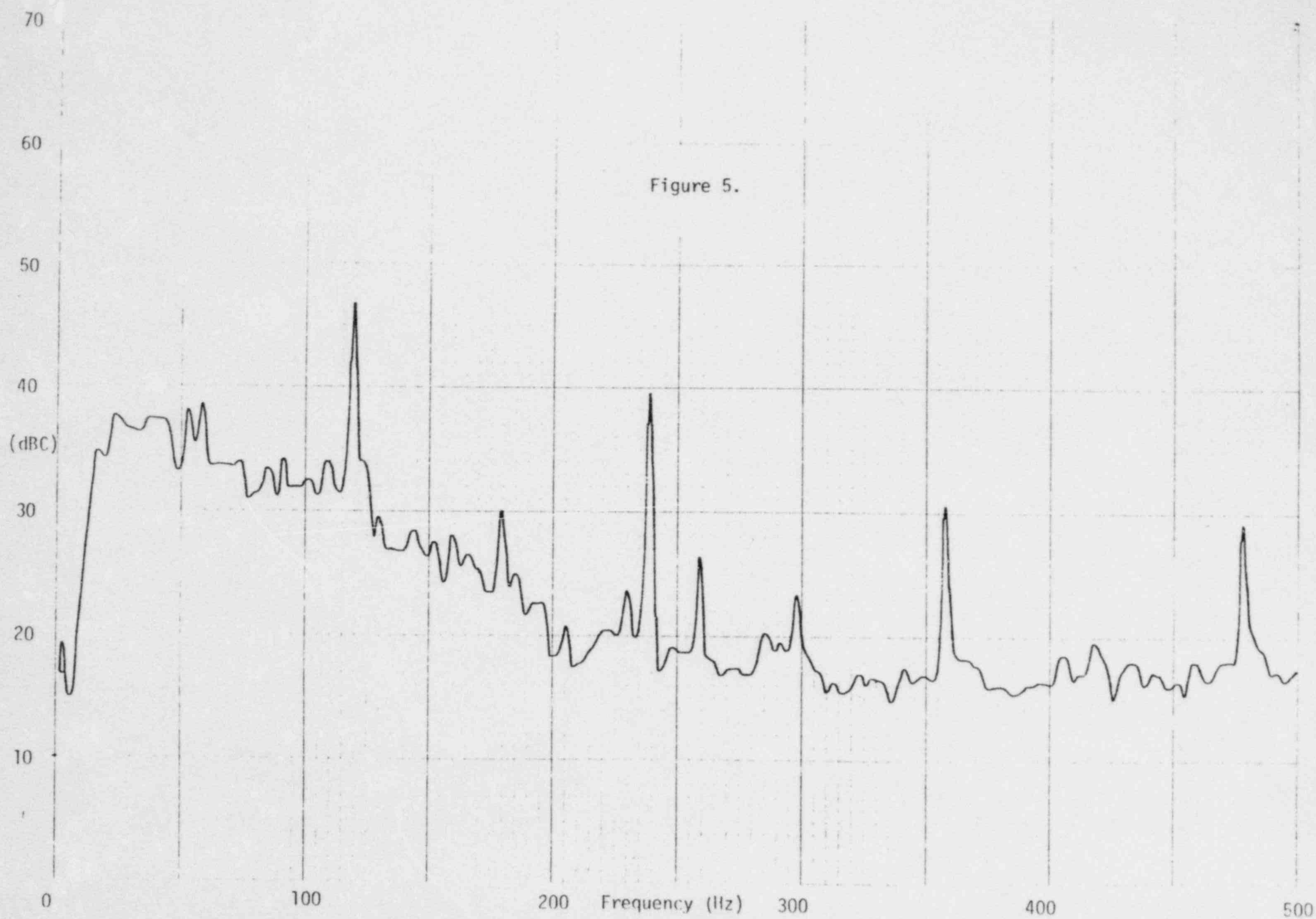


Figure 5.

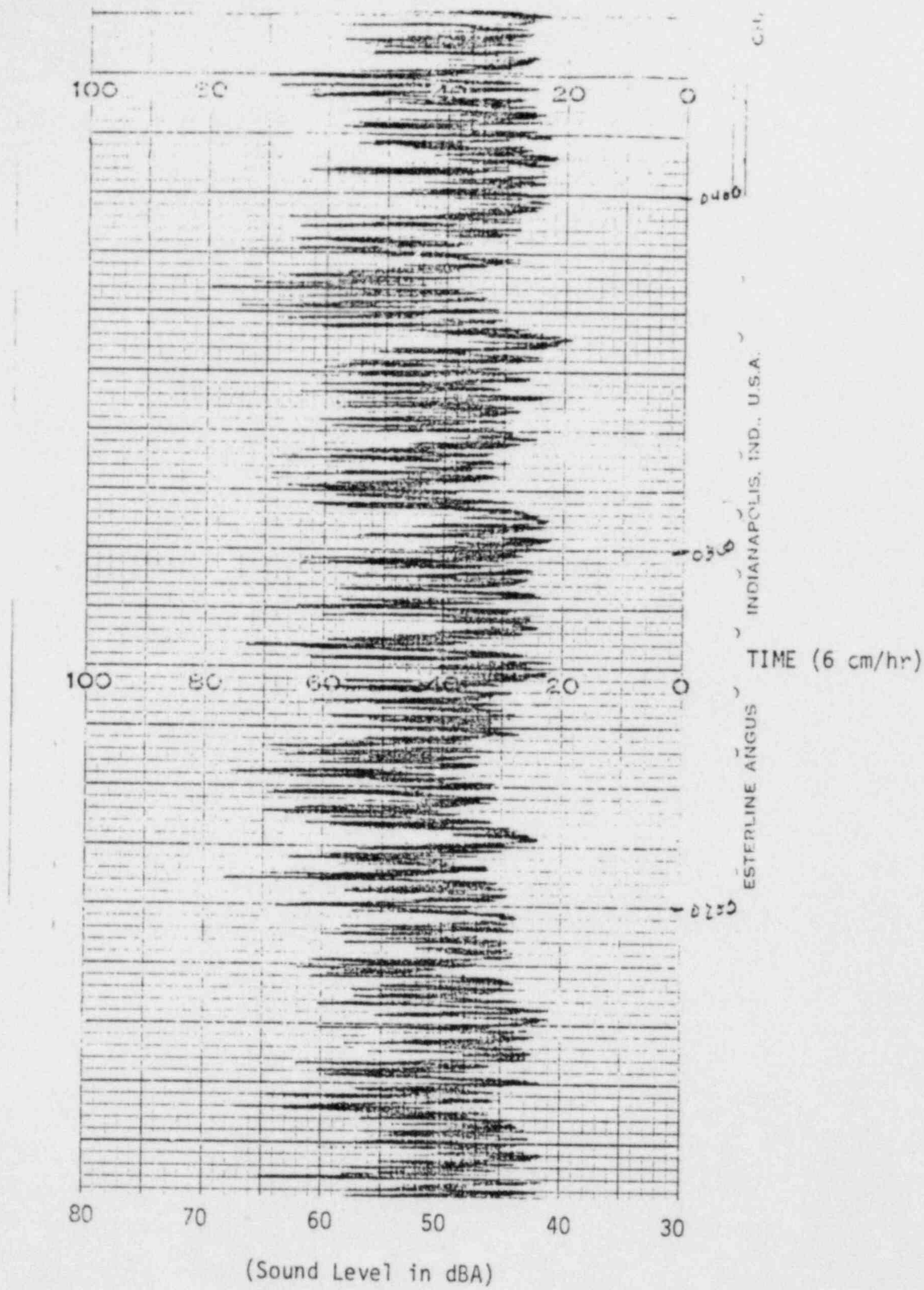


Figure 6. Effect of Excess Winds March 22, 1977

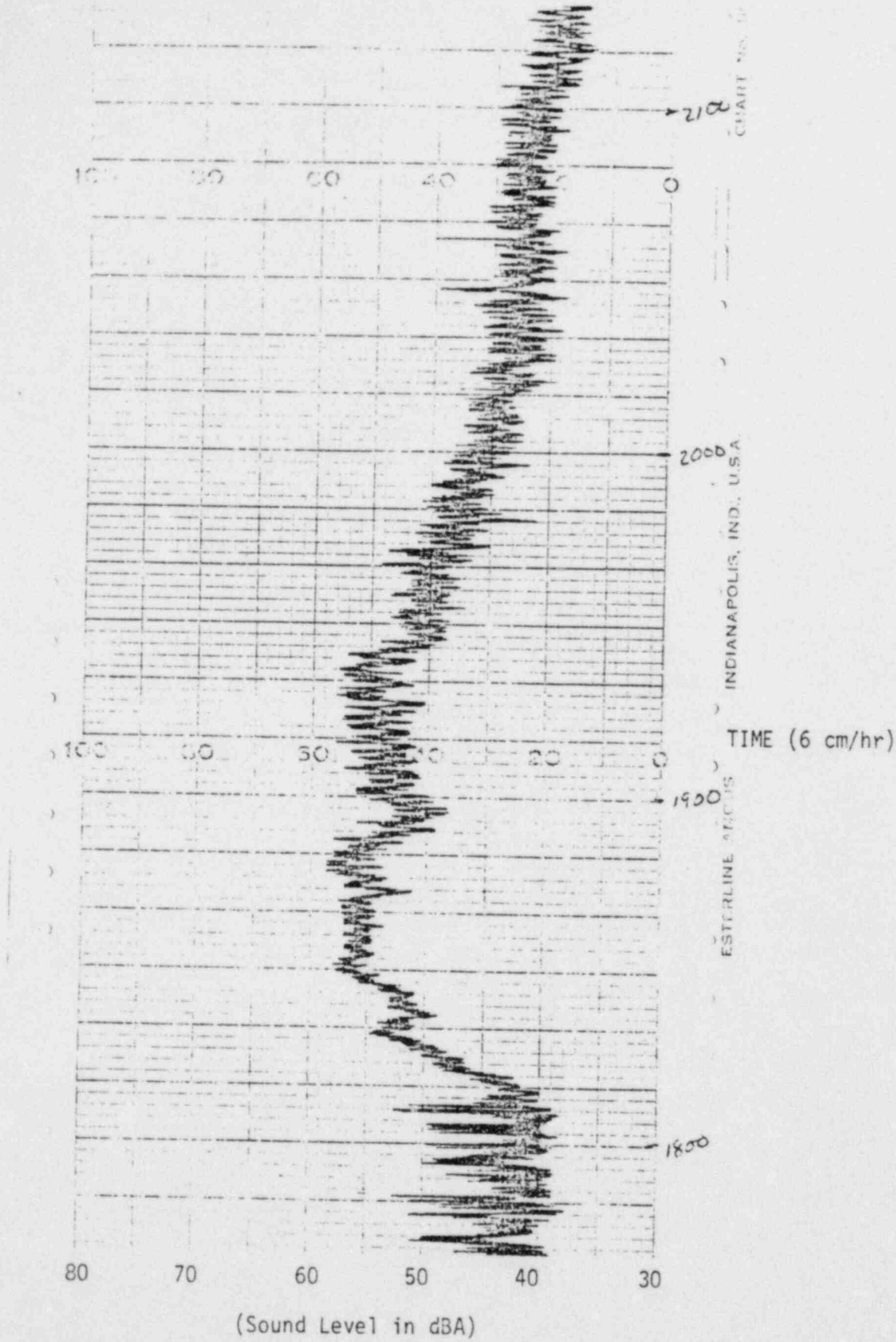


Figure 7. The "Cricket Phenomenon" March 26, 1977

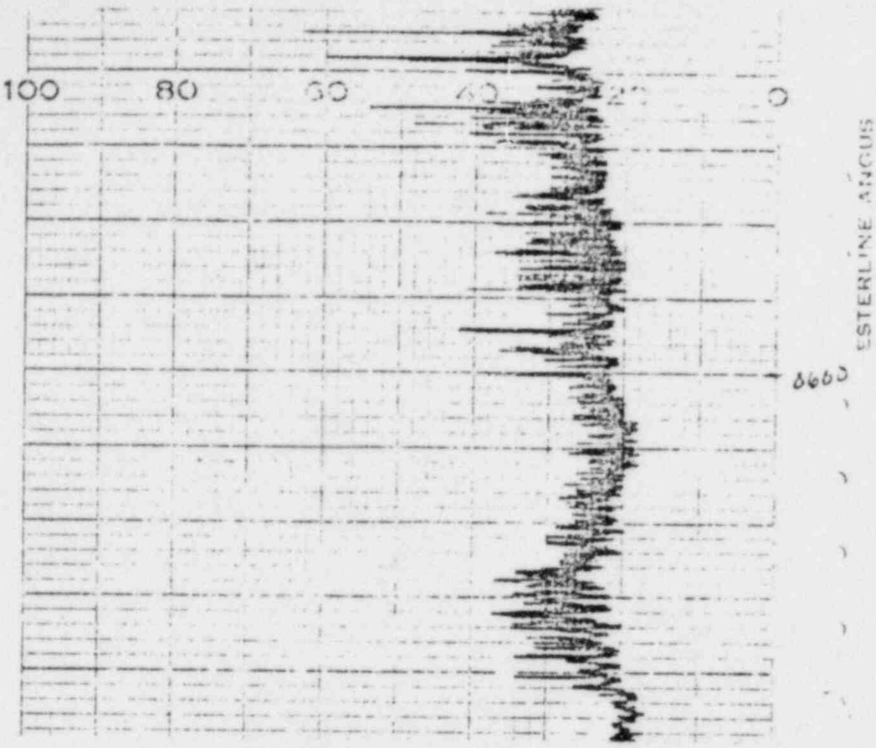


Figure 8a. "Normal" Conditions on March 29, 1977

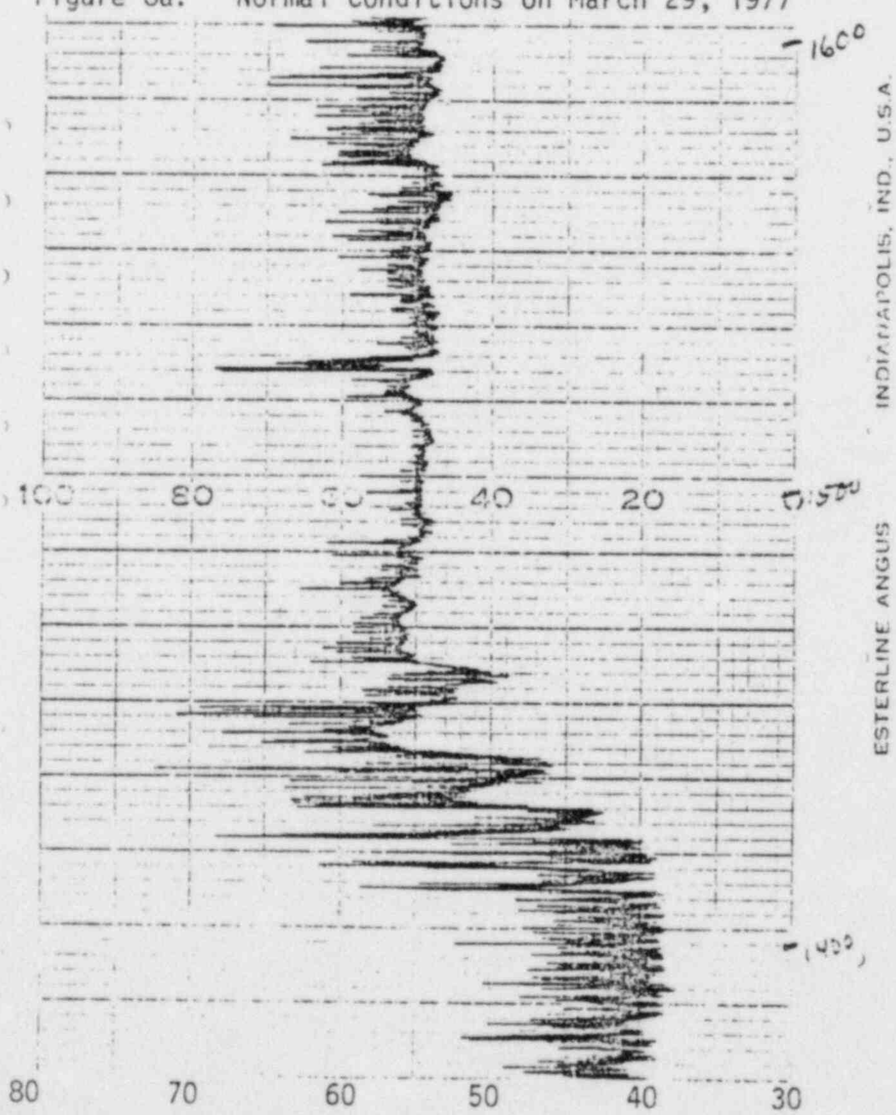


Figure 8b. Effect of Rainfall on March 29, 1977

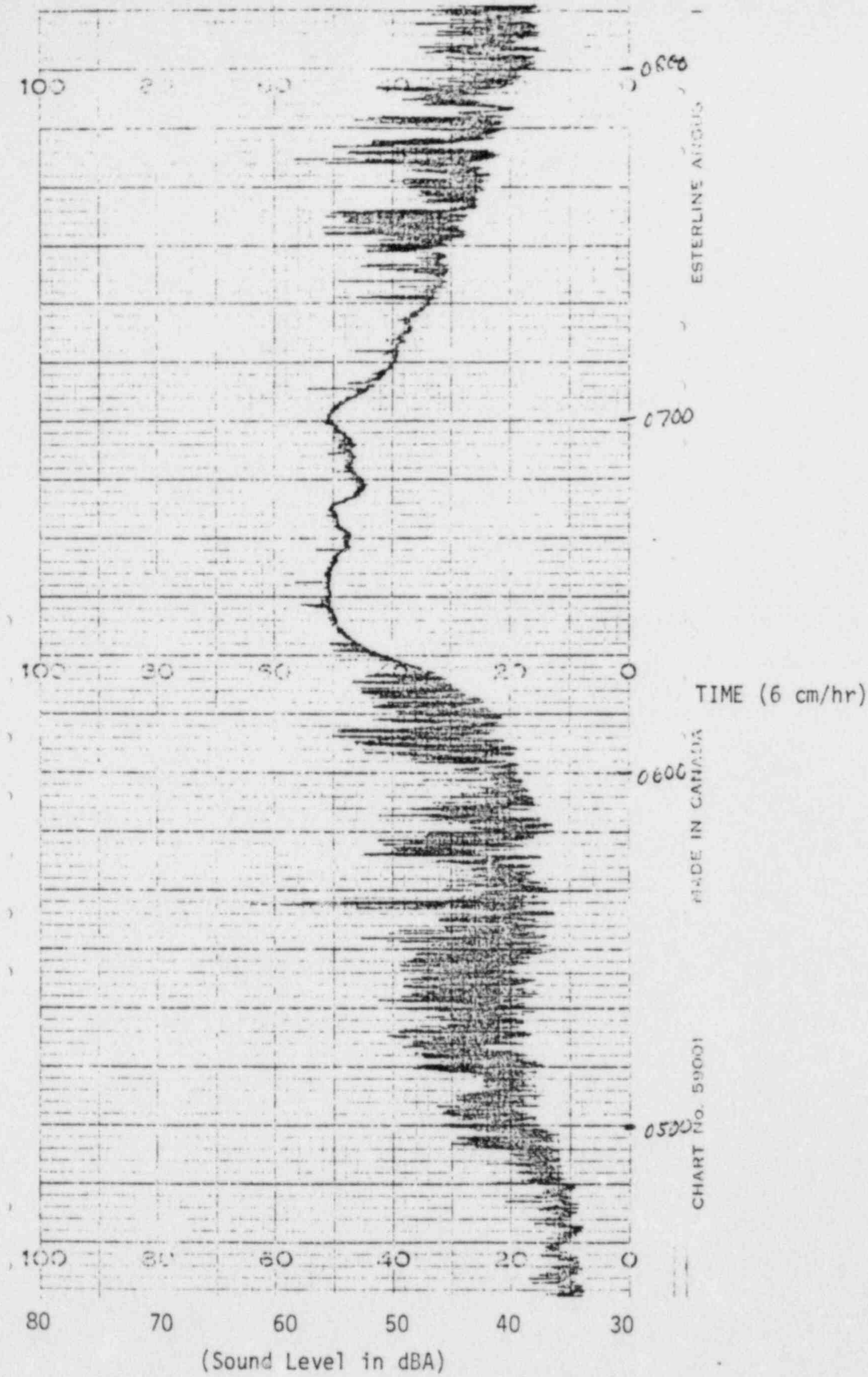


Figure 9. Effect of Rainfall on June 16, 1977

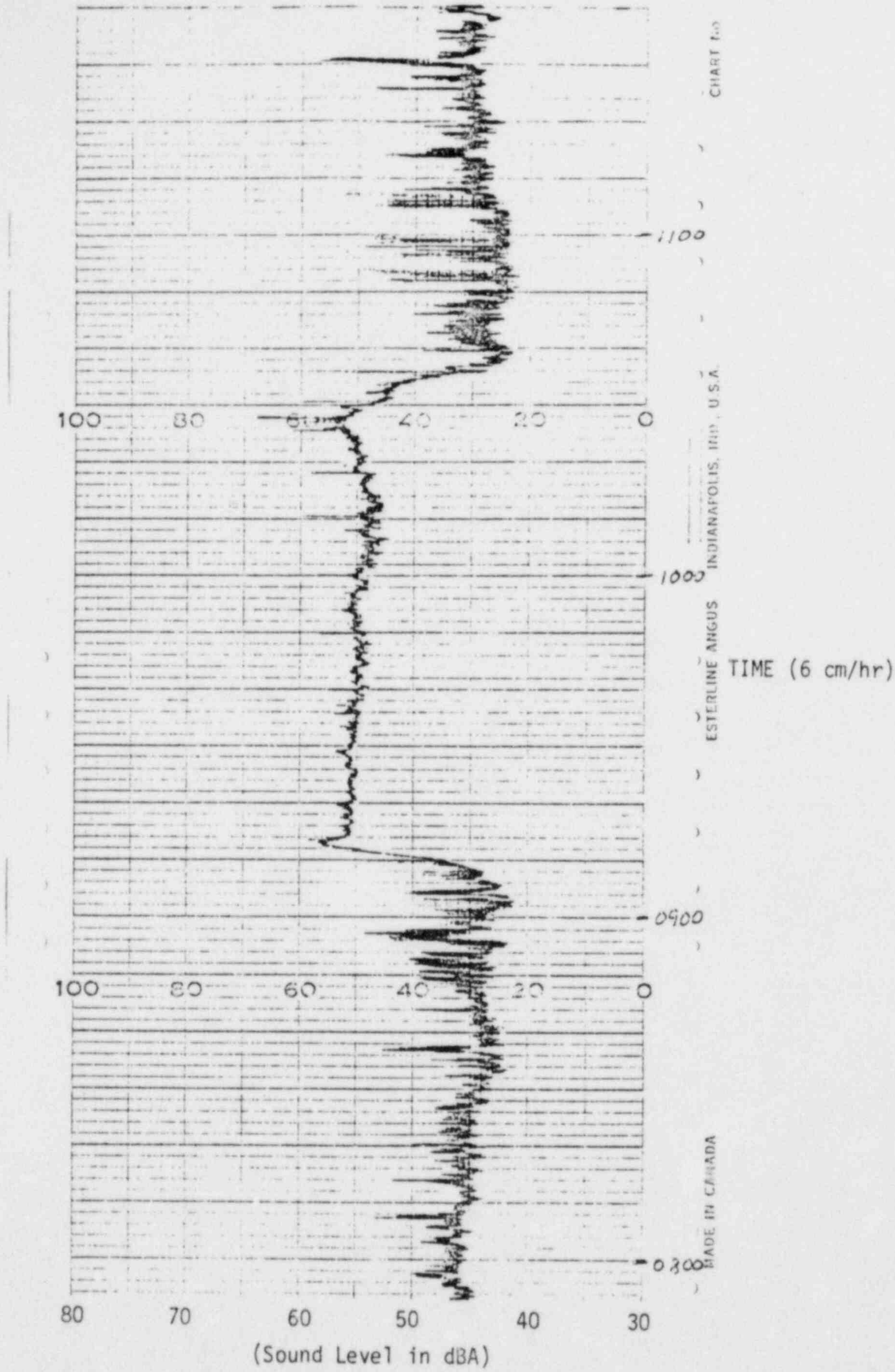


Figure 10. Effect of Rainfall on September 6, 1977

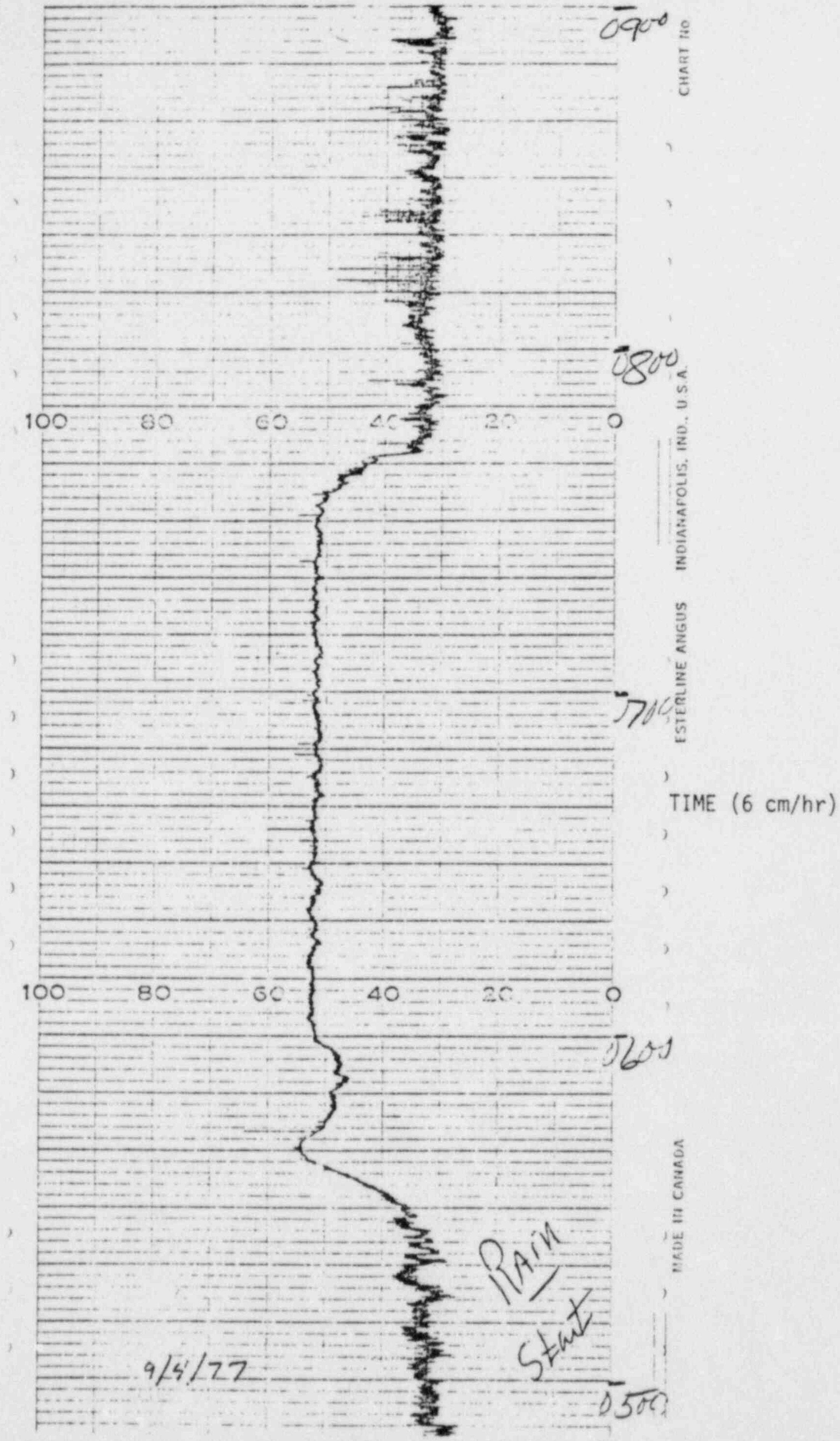


Figure 11. Effect of Rainfall on September 4, 1977

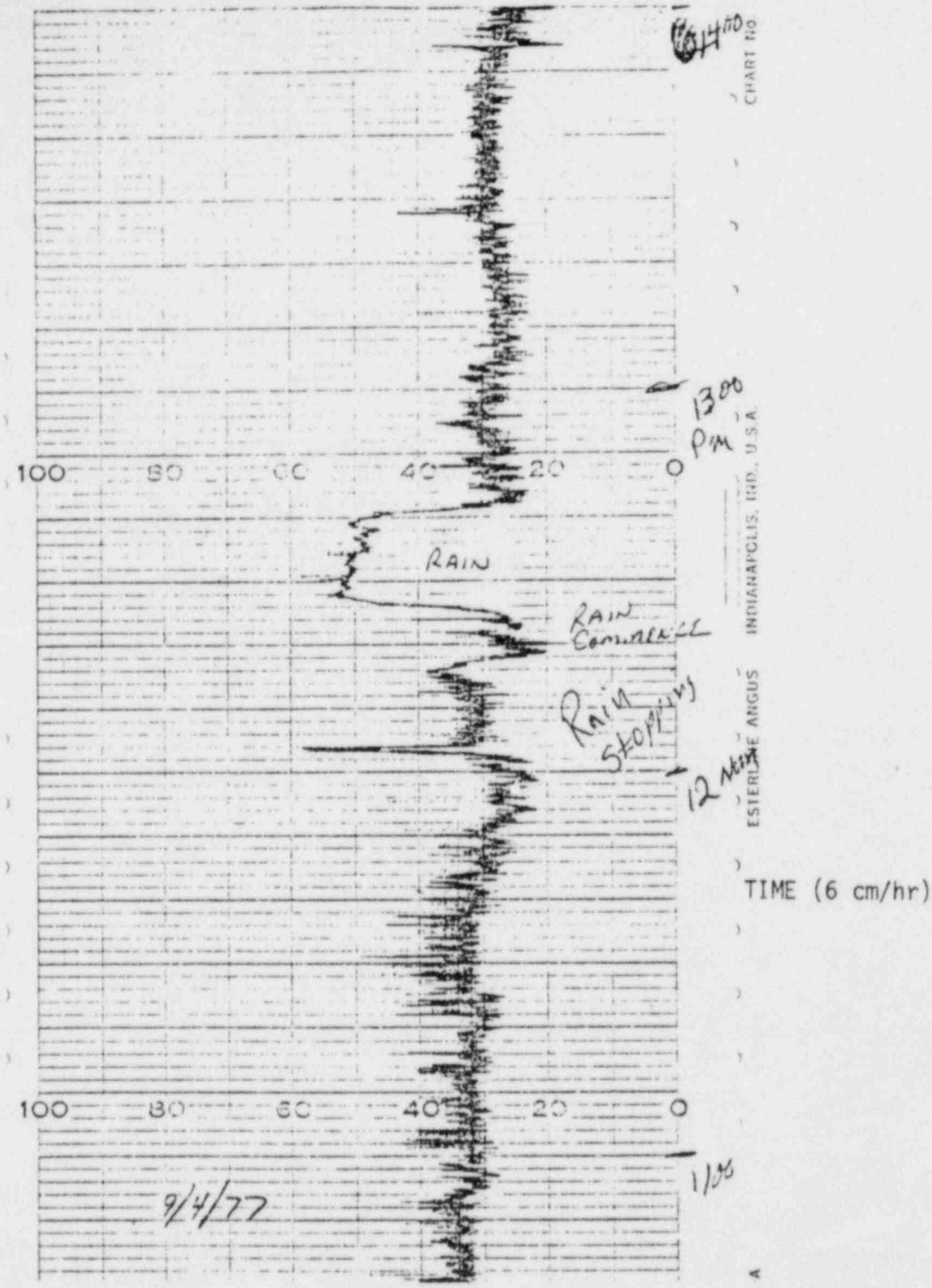


Figure 12. Effect of Rainfall on September 4, 1977

TABLE 2

SOUND LEVEL, METEOROLOGICAL, AND LINE LOAD DATA

DATE: 2/25/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (KW)
0100							
0200							
0300							
0400							
0500							
0600							
0700							
0800							
0900							
1000							
1100							
1200							
1300							
1400							
1500							
1600							
1700	44		S-SW	10[1]	25.0	2.0	UNAVAILABLE
1800	45		S	8[2]	22.0	3.0	"
1900	47		S-SE	6	21.0	3.5	"
2000	42		S-SE	4	20.0	3.0	"
2100	40	⊖	S-SE	10[3]	20.0	3.0	"
2200	40	⊖	S	10	20.0	4.0	"
2300	39	⊖	S	9[4]	19.0	4.5	"
2400	42	⊖	S	14	18.0	8.0	"

[1] GUSTS TO 18
[2] " " 15
[3] " " 23
[4] " " 20

DATE: 2/26/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SP(EED) (M…)
0100	42	⊖	S	[5] [illegible]
0200	37	⊖	S	[6] [illegible]
0300	37	⊖	S	[illegible]
0400	37	⊖	S	[illegible]
0500	38	⊖	S	[illegible]
0600	41	⊖	S	
0700	40	⊖	S	[7]
0800	44	⊖	S	[illegible]
0900	43	⊖	S-SW	[illegible]
1000	44	⊖	S-SW	[illegible]
1100	43	⊖	S-SW	[illegible]
1200	42	⊖	S-SW	[8]
1300	45	⊖	S-SW	
1400	45	⊖	S-SW	[illegible]
1500	48	⊖	S	[illegible]
1600	50	⊖	S	[illegible]
1700	50	⊖	S	[illegible]
1800	51	⊖	S-SE	[illegible]
1900	52	⊖	S-SE	[illegible]
2000	51	⊖	S	[illegible]
2100	48	⊖	S	[illegible]
2200	48	⊖	S	[illegible]
2300	61	0.35	SW	[9] [illegible]
2400	54	0.15	SW	

[5] GUSTS TO [illegible]
[6] " " [illegible]
[7] " " [illegible]
[8] " " [illegible]
[9] " " > [illegible]

DATE: 2/27/77

D ED H)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
3	18.0	11.0	UNAVAILABLE	56	0.03	W	9	16.0	13.5	UNAVAILABLE
	18.[illegible]	1[illegible].0	"	56	0.11	W	18	13.5	11.5	"
0	18.0	12.0	"	45	0	W-NW	15	11.5	9.5	"
0	16.5	12.5	"	43	0	W-NW	15	10.5	8.0	"
1	16.0	12.5	"	41	0	W-NW	15	9.5	6.5	"
1	15.5	12.5	"	40	0	W-NW	14	8.5	5.0	"
4	16.0	12.5	"	41	0	W-NW	15	8.0	4.5	"
1	16.5	12.5	"	40	0	W-NW	15	8.0	3.5	"
4	18.0	13.0	"	43	0	W-NW	15	7.0	3.0	"
4	20.0	12.5	"	43	0	W-NW	15	6.0	1.5	"
7	21.0	11.5	"	40	0	NW	14	6.0	0.5	"
5	23.5	11.0	"	41	0	NW	15	6.0	0.5	"
5	25.0	10.5	"	39	0	NW	13	6.0	0.5	"
5	26.0	10.0	"	39	0	N-NW	13	6.5	0.5	"
6	25.5	11.0	"	38	0	N-NW	10	7.5	0.5	"
9	25.5	11.5	"	37	0	N	8	8.5	0.5	"
6	25.0	11.5	"	37	0	N-NW	10	8.5	0	"
4	24.0	11.5	"	38	0	N-NW	10	7.0	-1.0	"
0	23.5	11.5	"	36	0	N-NW	7	5.0	-1.0	"
2	23.0	12.5	"	35	0	N-NW	7	3.5	-1.5	"
2	22.5	13.5		35	0	N-NW	7	3.5	-2.0	"
1	22.0	15.0		34	0	N-NW	6	3.0	-2.0	"
0	19.0	14.5		34	0	NW	3	2.5	-1.5	"
9	16.0	14.0		34	0	NW	1	1.5	-1.5	"

0
8
9
3
50

	DATE: 2/28/77							DATE: 3/1/77		
TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVE. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE ( )	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)
0100	34	0	NW	1	1.0	-1.5	UNAVAILABLE	37	0	
0200	34	0	NW	1	1.0	-1.5	"	38	0	S-SE
0300	34	0	N-NW	1	0.5	-1.5	"	37	0	S
0400	34	0	N-NW	1	0.5	-2.0	"	37	0	S-SW
0500	33	0	NW	1	0.0	-2.0	"	37	0	S-SW
0600	35	0	NW	1	-0.5	-2.0	"	39	0	S-SW
0700	41	0		0	-0.5	-2.0	"	40	0	S-SW
0800	41	0		0	0.5	-1.0	"	45	0	SW
0900	39	0	N-NW	7	2.0	-0.5	"	45	0	W-SW
1000	39	0	N-NW	11	5.0	-1.5	"	41	0	W
1100	38	0	N-NW	10	6.0	-2.5	"	46	0	W
1200	38	0	NW	10	8.0	-2.5	"	47	0	W-NW
1300	38	0	NW	[1]11	10.0	-3.5	"	47	0	W-NW
1400	37	0	NW	[2]10	11.0	-4.5	"	49	0	W-NW
1500	38	0	NW	12	12.0	-5.5	"	47	0	W-NW
1600	39	0	N-NW	11	12.0	-5.0	"	45	0	W-NW
1700	40	0	W-NW	14	11.5	-4.5	"	41	0	W-NW
1800	38	0	W-NW	10	10.0	-4.5	"	39	0	NW
1900	43	0	W-NW	8	8.5	-3.5	"	40	0	N-NW
2000	42	0	[3]	2	5.5	-3.0	"	38	0	N
2100	40	0		0	2.5	-1.5	"	37	0	N-NE
2200	39	0		0	1.5	-1.5	"	37	0	N-NE
2300	38	0		0	1.5	-1.5	"	37	0	NE
2400	38	0		0	1.5	-1.5	"	38	0	

[1] GUSTS TO 20
[2] " " 23
[3] W-NW TO SE

[4] GUSTS T…
[5] " …
[6] " …

DATE: 3/2/77

[AVG. WI]ND [SP]EED [(M]PH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0	1.5	-1.5	40.2	37	0	NE	3	5.0	-2.5	-97.0
4	3.0	-1.5	-7.7	37	0		0	4.0	-1.5	-72.1
4	3.5	-2.0	-46.5	37	0	E-NE	3	4.0	-1.5	-78.7
7	5.0	-2.0	-53.7	37	0	E	4	4.0	-2.5	-82.2
9	4.5	-2.0	-26.3	37	0	E	6	4.0	-3.0	-45.8
10	4.5	-1.5	-27.5	37	0	E	9	4.0	-3.0	-13.4
10	5.0	-1.5	-71.2	38	0	E	8	4.0	-3.5	-43.6
10	6.5	0.5	-118.1	38	0	E-SE	10	5.0	-2.5	-113.3
11	9.0	0	-80.0							
18	12.0	0	-62.6							
16	13.0	-0.5	-32.9	38	0	SE	7	12.0	-4.5	-91.3
18	14.0	-1.0	-28.2	36	0	SE	5	14.0	-4.5	-114.3
20	15.0	-1.5	-33.4	35	0	S	3	15.0	-4.5	-121.1
20	15.0	-2.0	-41.5	34	0	SE	4	16.0	-5.0	-104.0
21	15.0	-2.5	-44.3	36	0	SE	4	16.5	-5.0	-78.2
16	14.5	-3.0	-33.2	38	0	SE	5	16.0	-4.5	-52.0
12	14.0	-2.5	-39.2	37	0	SE	2	15.5	-4.0	-61.5
8	12.0	-2.5	-43.6	38	0	SE	3	15.0	-2.5	-80.0
4	11.5	-3.5	-81.2	46	0	SE	6	14.0	-2.5	-126.4
6	9.0	-4.5	-87.2	43	0	SE	10	14.0	-2.5	-98.3
3	8.0	-4.5	-68.0							
4	6.0	-4.0	-105.2							
2	6.0	-3.5	-94.7							
0	4.5	-2.5	-111.3							

17
33
33

DATE: 3/3/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100							
0200							
0300							
0400							
0500							
0600							
0700							
0800							
0900							
1000							
1100							
1200	46	0.01	SE	[2]16	12.0	8.5	108.6
1300	49	0.12	SE	[3]10	12.5	9.0	112.6
1400	53	0.11	S-SE	7	12.5	9.5	105.6
1500	[1]51	<0.01	SE	14	13.0	10.5	101.8
1600	45	0.01	S-SE	15	14.5	11.0	104.9
1700	48	0	S-SE	20	17.0	10.5	107.4
1800	52	0	S-SE	[4]25	18.0	9.5	66.1
1900							
2000							
2100							
2200							
2300							
2400							

[1] 41-60 dBA

[2] GUSTS TO 25
[3] " " 17
[4] " " 40

DATE: 3/7/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)
1400	42	0	N-NW
1500	43	0	N-NW
1600	40	0	N-NW
1700	39	0	N-NW
1800	[5]45	0	N
1900	52	0	E
2000	49	0	
2100	45	0	
2200	43	0	
2300	41	0	
2400	41	0	E

[5] 37-52dBA

DATE: 3/8/77

[cut off] (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
				41	Ø		2	2.5	-0.5	-45.0
				40	Ø		2	2.0	0	-67.4
				39	Ø		Ø	1.5	0	-73.8
				39	Ø		Ø	1.5	-0.5	-57.4
				40	Ø		Ø	1.0	-0.5	-44.0
				41	Ø		4	1.0	-0.5	-19.6
				42	Ø		4	2.0	0	-65.5
				38	Ø		2	3.5	1.0	-75.6
				37	Ø		3	10.0	2.5	-103.8
				37	Ø		5	12.5	3.5	-91.7
				38	Ø		6	15.0	0	-70.2
				37	Ø		6	16.5	-1.0	-47.1
				38	Ø		5	18.5	-0.5	18.5
4	14.5	-2.0	1.7	38	Ø		6	18.5	-0.5	20.9
4	14.5	-2.5	13.5	37	Ø		7	19.5	-1.0	39.1
3	14.5	-2.5	17.5	37	Ø		5	19.5	-1.0	30.6
0	14.5	-1.5	2.7	37	Ø		5	19.5	-1.5	20.4
4	13.0	-1.5	-20.2	39	Ø		2	15.0	-0.5	1.8
1	9.5	1.0	-71.0	36-57	Ø		3	11.5	2.5	12.3
Ø	6.0	2.0	-54.3	57	Ø		1	9.5	3.5	23.2
Ø	5.0	1.5	-31.8	56	Ø		4	9.5	2.0	38.3
Ø	4.0	1.0	-47.1	46	Ø		7	12.5	1.5	-29.3
Ø	4.0	0.5	-69.5	43	Ø		7	12.5	1.0	-76.2
2	3.0	Ø	-60.3	41	Ø		6	11.0	1.0	-44.2

	DATE: 3/9/77							DATE: 3/10/77			
TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AV. WI[ND] SP[EED] (M[PH])
0100	41	0		6	11.0	0	13.6	39	0		8
0200	43	0		4	8.0	1.0	25.4	40	0		9
0300	42	0		5	8.5	0.5	23.8	40	0		10
0400	42	0		8	11.0	-0.5	46.8	40	0		9
0500	40	0		8	9.0	-1.0	48.6	41	0		11
0600	41	0		5	8.5	-1.0	70.1	41	0		1
0700	40	0		4	7.5	-0.5	68.5	42	0		1
0800	44	0		8	9.5	0	24.9	44	0		1
0900	42	0		9	12.5	0.5	35.7	41	0		[2]1
1000	40	0		8	15.0	2.0	52.1	45	0		[2]1
[illegible]00	40	0		10	16.5	1.5	65.0	45	0		1
1200	41	0		[1]11	19.0	0	90.9	45	0		1
1300	39	0		10	19.0	-1.0	69.7	43	0		1
1400	40	0		10	19.5	-1.0	63.0	42	0		1
1500	40	0		10	20.0	-0.5	50.2	43	0		1
1600	45	0		8	19.5	-1.0	104.7	43	0		9
1700	45	0		8	18.5	-0.5	101.4	44	0		12
1800	39	0		6	17.0	0	65.6	45	0	SE	[2]15
1900	46	0		6	15.5	0	33.7	54	0	SE	[2]15
2000	50	0		6	14.5	0.5	49.6	51	0	SE	[2]14
2100	48	0		6	14.5	1.0	35.7	48	0	SE	15
2200	44	0		6	13.0	1.5	-14.2	45	0	SE	13
2300	42	0		7	13.0	2.5	-29.2	43	0	SE	10
2400	40	0		8	13.0	2.5	-64.1	41	0	SE	12

[1]GUSTS TO 18

[2]GUSTS TO 2

DATE: 3/11/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (average dBA)	Rainfall (inches)	Wind Direction (main)	Avg. Wind Speed (mph)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
13.0	2.0	-66.4	41	0	SE	12	13.5	11.5	-47.1
13.0	2.5	-32.0	41	0	SE	13	14.0	11.5	-31.0
12.5	2.5	-22.2	41	0	SE	12	14.0	11.5	-23.8
12.5	2.5	-9.8	42	0	SE	12	14.0	12.0	-32.3
12.5	3.5	18.5	42	0	SE	13	14.0	12.0	6.0
12.0	4.5	67.9	42	0.10	SE	12	14.5	12.5	56.1
12.5	5.0	99.0	49	0.01[3]	SE	10	14.5	12.5	86.3
13.0	5.5	75.7	45	0.01	E-SE	14	15.0	13.0	52.1
14.5	7.0	85.0	43	0	E-SE	14	15.0	13.5	60.0
16.0	8.5	88.5	43	0.02[4]	SE	13	15.5	14.0	74.4
17.5	9.0	87.6	42	0	SE	12	16.0	14.5	85.5
18.5	9.0	78.4	41	0	SE	15	17.5	15.0	82.7
18.0	8.5	61.4	42	0	S-SE	14	18.5	15.0	116.5
17.5	9.0	45.7	42	0	S-SE	12	18.5	15.0	91.6
16.5	9.5	46.5	41	0	SE	13	18.5	15.5	100.9
15.0	10.5	49.1	40	0	S-SE	13	19.0	16.0	133.7
14.0	11.0	44.4	40	0	S-SE	13	19.0	16.0	118.6
14.0	11.0	27.6	49	0	SE	15	19.0	16.0	85.5
14.0	11.0	28.3	56	0	SE	15	19.5	16.0	64.9
14.0	11.0	18.1	53	0	SE	19	19.5	16.0	88.3
14.0	11.0	35.3	48	0	S-SE	19	20.0	16.0	116.7
14.0	11.0	-31.7	48	0	S-SE	22	20.0	16.5	73.2
13.5	11.5	-70.8	48	0	S-SE	23	20.5	16.5	66.9
13.5	11.5	-71.3	48	0	S-SE	21	20.5	16.5	47.1

[3] @ 0830 S.L. increased to 59 dBA during rain
[4] @ 0950 S.L. increased to 55 dBA during rain

DATE: 3/12/77 | DATE: 3/14/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	53 (42-67)	0.08	S/SE	[1]21	20.0	17.0	-0.8				
0200	49	0.19	S	20	19.5	17.0	-32.5				
0300	58	0.10	S-SE	20	19.5	17.0	-26.3				
0400	59	0.50	S-SE	19	19.5	17.5	-0.7				
0500	55	0.25	S-SE	[2]18	19.5	17.5	12.6				
0600	55	1.25	S-SE	20	19.5	17.5	-16.5				
0700											
0800											
0900											
1000											
1100											
1200											
1300											
1400											
1500								41	0	SW	7
1600								43	0	SW	6
1700								40	0	SW	6
1800								41	0	W-SW	3
1900								56	0	E	3
2000								58	0	SE	3
2100								47	0	S	5
2200								46	0	E-SE	4
2300								43	0	S-SE	6
2400								43	0	S-SE	6

[1] Gusts to 35
[2] " " 30

DATE: 3/15/7[illegible]

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
			42	0	S-SE	8	16.5	4.5	-15.6
			42	0	S	9	17.5	4.0	-16.7
			42	0	S	8	16.5	4.5	-24.7
			43	0	S-SW	6	15.5	5.0	-3.5
			43	0	S-SW	5	15.0	6.0	23.9
			43	0	SE	5	14.0	6.5	93.8
			44	0	SE	3	13.0	7.5	134.5
			45	0	S-SE	5	15.0	9.0	60.3
			43	0	S-SE	6	16.5	10.0	24.3
			42	0	S	6	17.0	11.5	7.2
			40	0	S-SW	6	18.5	14.0	-13.2
			39	0	SW	6	19.5	14.5	-0.8
			38	0	SW	6	22.0	15.5	15.0
			38	0	SW	7	24.5	16.5	12.2
26.0	2.5	41.1	38	0	W-SW	7	25.5	16.5	13.0
26.0	2.5	54.8	37	0	SW	8	26.0	16.5	19.2
26.0	3.0	41.1	38	0	S-SW	7	26.0	16.5	19.2
23.0	3.5	7.8	40	0	S-SW	6	24.5	16.5	29.6
17.5	8.0	-21.7	55	0	S-SW	6	23.0	16.5	11.7
15.5	8.0	2.5	50	0	S-SW	5	22.0	16.5	26.6
17.0	5.0	20.2	44	0	SW	5	22.0	16.5	66.1
15.0	5.0	-16.2	40	0	W-SW	4	21.5	16.5	41.0
15.5	5.5	-32.7	40	0	W-SW	5	21.0	16.0	-15.8
15.0	5.5	-31.5	40	0	W	5	20.5	15.5	-36.8

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	DATE: 3/16/77							DATE: 3/17/77			
TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	41	0	S	3	18.0	14.5	-18.9	42	0	NE	6
0200	40	0	W	5	17.0	14.5	0.8	43	0	N-NE	6
0300	36	0	NW	7	17.5	14.5	8.7	43	0	N-NE	6
0400	40	0	N	15	16.5	13.0	0.5	43	0	NE	6
0500	40	0	N	[1]14	15.5	10.0	33.2	43	0	NE	3
0600	40	0	N	13	14.0	7.5	105.8	42	0	E	[3]9
0700	43	0	N	13	13.5	7.0	138.7	43	0	E-NE	4
0800	44	0	N	15	13.5	6.5	101.1	44	0	E-SE	6
0900	45	0	N	17	14.0	6.0	64.5	45	0	E-SE	9
[illegible]	41	0	N	15	15.0	5.0	73.0	43	0	SE	7
1100	43	0	N	14	16.0	3.0	64.7	44	0	SE	[4]10
1200	41	0	N	14	16.5	2.5	57.0	42	0	S-SE	[4]12
1300	43	0	N	15	17.5	1.0	64.0	42	0	S	10
1400	43	0	N	14	18.5	0.5	41.3	41	0	S	10
1500	43	0	N	15	18.5	-0.5	46.3	41	0	S	7
1600	43	0	N	[2]12	18.5	-1.0	63.2	43	0	S	9
1700	42	0	N	9	17.5	-1.5	62.5	43	0	S	9
1800	43	0	N	5	16.0	-0.5	44.3	44	0	S	9
1900	49	0	N-NE	3	13.5	0	0.7	50	0	S	[5]11
2000	49	0	NE	3	12.0	0.5	21.7	47	0	S	13
2100	48	0	NE	1	10.0	2.0	37.3	43	0	S-SE	13
2200	42	0	NE	5	11.5	0	13.3	45	0	S	[6]18
2300	42	0	NE	6	11.5	-2.0	14.4	44	0	S	18
2400	42	0	E-NE	7	11.5	-2.5	-13.6	44	0	S	17

[1] Gusts to 23
[2] " " 20

[3] Gusts to 19
[4] " " 20
[5] " " 17
[6] " " 29

DATE: 3/[illegible]/7[illegible]

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (Average dBA)	Rainfall (inches)	Wind Direction (From)	Avg. Wind Speed (mph)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
11.5	-2.5	-1.7	41	0	S	[7]13	19.0	13.5	65.5
10.5	-1.5	4.7	43	0	S-SW	[8]17	20.0	14.5	78.1
10.0	-1.5	40.9	46	0	S-SW	17	20.0	15.0	75.7
10.0	-1.5	47.8	45	0	S-SW	17	20.5	15.0	75.3
9.0	-0.5	76.8	46	0	SW	15	20.5	15.0	78.0
9.5	-1.0	126.8	44	0	SW	15	20.0	15.0	105.9
9.5	-1.0	172.4	45	0	SW	[9]12	20.0	14.5	161.4
10.0	0	108.8	45	0	SW	13	20.0	14.5	113.5
12.5	-0.5	79.5	46	0	SW	[10]13	20.5	14.5	67.2
14.0	-0.5	73.8	47	0	W-SW	16	21.5	14.5	58.1
16.0	0	78.1	47	0	W-SW	18	22.5	14.5	55.4
18.5	0	104.8	45	0	W-SW	16	23.0	13.5	61.2
20.0	0.5	113.8	44	0	W	15	24.5	12.0	68.0
20.0	2.0	104.8	43	0	W	15	25.0	8.5	74.1
20.5	3.5	103.9	43	0	W	15	24.5	7.5	76.2
22.0	5.0	113.1	43	0	W	14	24.0	6.0	83.6
22.0	6.5	92.0	40	0	W	[11]10	23.0	3.0	90.3
21.0	7.5	80.6	39	0	W-NW	10	21.5	2.5	77.3
20.5	8.5	46.9	48	0	W-NW	5	21.5	2.5	52.3
19.5	8.5	65.4	52	0	NW	4	19.0	2.5	54.0
19.0	8.[illegible]	72.3	40	0	N-NW	6	18.5	1.5	86.2
19.0	9.5	38.8	40	0	N	5	18.0	1.5	62.0
19.0	10.5	40.0	40	0	N	6	17.0	2.5	56.7
19.0	12.0	48.5	39	0	N-NE	5	16.0	3.5	91.8

[7] Gusts to 23
[8] " " 30
[9] " " 22
[10] " " 25
[11] " " 17

8406040266-08

DATE: 3/19/77 | DATE: 3/20/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	3/20/77 SOUND LEVEL (AVERAGE dBA)	3/20/77 RAINFALL (INCHES)	3/20/77 WIND DIRECTION (FROM)
0100	38	0	N-NE	5	15.0	3.5	110.1	39	0	
0200	38	0	N-NE	6	14.0	4.0	104.1	39	0	
0300	37	0	N-NE	7	13.0	4.5	75.9	39	0	
0400	45	0	N-NE	3	12.5	4.5	80.8	39	0	
0500	48	0	NE	5	12.0	4.5	91.1	40	0	
0600	48	0	N-NE	5	11.5	4.5	70.3	42	0	
0700	49	0	N-NE	6	11.5	4.5	56.4	52	0	
0800	49	0	NE	9	12.0	5.0	76.1	44	0	
0900	47	0	NE	8	13.5	4.5	68.8	40	0	
1000	43	0	E-NE	10	15.0	5.0	73.2	38	0	
1100	43	0	E-NE	10	16.5	5.5	88.3	37	0	
1200	39	0	E	7	19.0	5.0	71.8	37	0	
1300	40	0	NE	7	20.5	4.5	69.1	39	0	
1400	43	0	N-NE	[1]10	21.5	4.5	61.1	39	0	
1500	43	0		6	21.5	4.5	49.9	41	0	
1600	40	0		4	19.5	6.0	71.6	43	0	
1700	45 (36-50)	0		7	18.0	6.5	97.0	44	0	
1800	49	0		8	17.5	6.5	95.6	44	0	
1900	49	0		7	17.5	6.0	91.8	47	0	
2000	48 (36-65)	0.15		[2]10	16.5	6.5	72.1	50	0	
2100	55	0.05		11	11.5	8.5	71.5	47	0	
2200	46	0.05		[3]10	11.0	9.0	54.4	44	0	
2300	51	0		8	11.0	9.0	58.7	41	0	
2400	39	0		8	10.0	8.5	62.7	41	0	

[1] Gusts to 18
[2] " " 33
[3] " " 28

[4] Gusts to

DATE: 3/21/77

AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
5	10.0	8.5	72.9	41	0		7	13.5	[illegible]	39.2
4	10.0	8.5	66.6	40	0		7	13.0	2.0	[illegible]
4	9.5	8.0	64.2	41	0		10	13.5	[illegible]	45.5
3	9.5	8.0	64.6	41	0		3	12.5	2.5	[illegible]
3	9.0	7.5	67.7	43	0		3	11.0	4.0	42.1
4	8.0	7.0	67.1	42	0		9	12.5	3.0	[illegible]
4	8.0	7.0	93.2	43	0		13	13.5	[illegible]	[illegible]
6	8.5	7.5	99.1	44	0		14	13.5	3.5	81.7
[4]10	11.0	6.0	84.4	50	0		20	13.0	5.5	56.8
8	12.5	1.5	72.4	48	0		18	12.5	7.0	47.2
7	14.0	1.5	80.3	49	0.04		18	12.0	8.5	39.5
6	15.0	1.5	79.0	58	0.21		17	12.0	10.0	51.8
5	16.5	1.5	59.5	58	<0.01		13	12.0	10.0	65.0
6	17.0	0.5	39.5	57	0.21		[5]12	12.0	10.0	66.5
6	17.5	0.5	31.1	55	0.24		12	12.0	10.0	77.2
5	17.5	0.5	86.9	56	0.05		13	11.5	10.0	92.9
3	17.5	0.5	120.1	59	0.10		[6]20	11.5	10.0	78.6
4	16.5	1.5	110.5	55	0.06		25	12.0	10.5	45.7
4	15.0	2.5	137.6	52	<0.01		[7]11	12.0	10.5	34.2
0	13.5	3.5	142.4	53	0		16	12.0	10.5	48.6
1	13.0	4.5	145.4	51	0		15	12.0	10.0	52.9
0	12.5	4.5	103.9	47	0		10	11.5	10.0	42.1
2	13.0	3.0	67.7	45	0		9	12.0	10.0	17.2
6	13.5	2.0	57.4	43	0		8	12.0	10.5	20.5

21

[5] Gusts to 25
[6] " " 36
[7] " " 23

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8406040266-09

DATE: 3/22/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100	44	0	N	16	12.0	8.5	29.8
0200	50	0	N	[1]22	11.5	4.5	20.0
0300	50	0	N	20	7.5	2.0	36.2
0400	51	0	N	20	5.5	0	43.3
0500	48	0	N	[2]18	5.0	-1.5	79.5
0600	43	0	N	[3]13	4.0	-1.5	125.1
0700	43	0	N	13	4.0	-1.5	134.7
0800	43	0	N	15	5.0	-0.5	81.4
0900	44	0	N	15	6.0	-0.5	68.1
1000	46	0	N	18	8.0	-1.0	87.8
1100	46	0	N	16	8.5	-1.5	97.3
[illegible]0	45	0	N	16	10.0	-2.5	83.7
1300	45	0	N	15	11.0	-2.5	87.7
1400	44	0	N	15	12.0	-3.0	81.5
1500	44	0	N	15	12.5	-3.0	87.0
1600	43	0	N	12	12.5	-3.5	92.9
1700	43	0	N	12	12.5	-4.0	83.9
1800	42	0	N	8	11.0	-4.5	73.0
1900	44	0	N	5	9.5	-3.0	33.6
2000	47	0	N	1	5.5	-1.0	42.7
2100	46	0	N	1	4.5	0	56.1
2200	44	0	N	1	5.0	-1.0	54.4
2300	44	0	N	2	3.5	-1.0	49.9
2400	43	0	N	3	3.5	-1.0	20.7

[1] GUSTS TO 40
[2] " " 37
[3] " " 24

DATE: 3/23/77

SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
44	0	N	3
43	0	N	3
41	0	N	3
42	0		6
42	0	N	1
44	0	N	1
45	0		6
43	0	N	3
42	0	N	4
40	0	N	6
41	0	N	6
42	0	N	5
41	0	N	[4]9
41	0	N	1
40	0	N	9
40	0		
40	0		
41	0		
46	0		
52	0		
46	0		
45	0		
44	0		
43	0		

[4] GUSTS TO 1

DATE: 3/24/77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
3.5	-2.5	22.3	43	Ø			5.0	2.0	-13.1
3.0	-3.5	45.8	41	Ø			4.0	1.5	9.2
3.0	-4.5	66.1	41	Ø			3.5	1.5	15.1
1.0	-4.0	80.4	40	Ø			3.0	1.0	29.3
0	-3.5	113.6	40	Ø			3.5	1.5	37.0
-1.0	-2.5	151.8	42	Ø			2.5	1.0	102.6
0.5	-1.0	125.2	43	Ø			5.0	2.5	114.9
3.0	-1.0	100.7	42	Ø			7.5	3.5	66.9
6.5	-0.5	75.2	41	Ø			10.5	3.0	81.6
10.0	-3.0	74.9	40	Ø		7	14.0	1.0	89.5
11.5	-3.5	70.7	38	Ø		8	16.0	1.5	72.9
14.0	-2.5	66.6	39	Ø		[5] 10	18.0	1.0	78.9
16.0	-2.0	70.4	41	Ø		9	19.0	-2.0	99.8
17.0	-1.5	48.4	39	Ø		[6] 8	19.5	-3.0	90.0
18.5	-1.5	49.9	38	Ø		6	19.5	-5.0	82.3
18.5	-1.0	50.0	40	Ø		7	20.0	-4.5	79.0
19.0	-0.5	22.5	39	Ø		5	19.5	-5.0	41.1
18.0	-0.5	0.2	40	Ø		3	17.5	-3.0	34.9
15.0	0	20.0	50	Ø		3	14.0	3.0	28.0
9.5	2.0	29.8	47	Ø		4	14.5	2.0	14.6
7.5	3.0	39.2	40	Ø		5	14.5	-2.5	31.6
7.0	3.0	10.2	40	Ø		4	14.5	-2.5	23.4
6.0	2.5	1.4	39	Ø		5	13.0	-1.5	-21.8
6.0	2.5	-12.9	39	Ø		4	13.0	-1.0	-35.9

[5] gusts to 20
[6] " " 20

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8406040266 -10

DATE: 3/25/77 DATE: 3/26/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM
0100	39	0		8	12.5	-1.0	-14.1	49	0	
0200	39	0		7	13.5	-2.0	1.2	49	0	
0300	39	0		5	12.5	-1.0	44.7	48	0	
0400	41	0		3	10.5	1.0	69.2	48	0	
0500	42	0		3	10.0	2.0	77.9	49	0	
0600	43	0		3	7.5	3.0	81.5	50	0	
0700	44	0		2	9.0	3.0	98.4	44	0	
0800	42	0		4	13.5	2.0	95.1	42	0	
0900	40	0		6	15.0	3.0	96.6	42	0	
1000	42	0		7	20.0	3.0	109.7	41	0	
1100	41	0		7	21.5	-1.0	102.9	43	0	
1200	39	0		7	21.5	-4.0	125.5	40	0	
1300	37	0		7	22.0	-2.5	128.4	41	0	
1400	39	0		7	23.0	-1.5	123.6	43	0	
1500	39	0		7	23.5	-2.0	115.2	40	0	
1600	38	0		5	23.5	-2.0	94.4	40	0	
1700	38	0		5	23.0	-2.5	77.7	41	0	
1800	41	0		2	20.0	-1.0	63.0	41	0	
1900	52	0		3	14.5	5.5	78.7	53	0	
2000	52	0		3	12.5	5.0	75.0	49	0	
2100	47	0		3	11.0	4.0	74.2	42	0	
2200	48	0		3	11.0	4.5	64.6	40	0	
2300	50	0		3	11.5	4.0	42.7	39	0	
2400	49	0		0	10.0	3.5	41.3	38	0	

DATE: 3/27/77

AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
1	9.0	4.0	45.1	37	0		7	17.5	8.0	43.9
3	8.5	3.5	38.4	37	0		7	17.5	8.5	69.8
3	9.0	3.5	70.2	38	0		6	17.5	8.0	57.8
3	9.5	3.0	83.4	39	0		4	17.0	7.5	67.3
1	9.0	2.5	81.8	40	0		4	16.0	7.5	76.8
0	8.0	2.5	80.1	41	0		7	16.0	7.5	91.9
4	11.0	4.0	100.1	43	0		12	16.0	7.5	98.3
8	15.0	4.5	138.2	44	0		13	17.0	8.5	127.0
8	18.0	4.5	140.8	46	0		[1] 15	19.0	9.0	74.7
6	20.0	5.5	156.9	45	0		16	21.5	9.5	52.3
9	21.5	6.0	139.3	47	0		[2] 18	23.0	10.5	41.3
9	23.5	6.0	139.0	48	0		20	24.5	11.5	44.6
10	24.0	5.5	130.6	49	0		20	25.0	11.5	39.7
9	24.5	5.5	141.1	46	0		19	25.0	12.0	6.6
7	24.5	5.5	143.5	47	0		19	24.5	12.5	18.6
7	24.5	6.0	145.2	44	0		17	23.5	12.5	8.2
8	23.5	6.0	131.0	43	0		16	23.5	12.5	11.5
5	21.5	5.5	107.7	43	0		17	23.5	11.5	18.4
4	17.5	7.0	115.4	51	0		17	23.0	10.0	17.7
5	16.0	7.0	105.2	48	0		14	22.5	10.0	18.4
6	18.0	7.0	109.0	47	0		17	22.5	9.5	4.2
6	18.0	7.5	83.0	49	0		[3] 20	22.0	8.5	5.9
5	16.5	8.0	59.7	55	0		[4] 25	21.5	5.0	-32.3
6	18.0	8.0	32.7	50	0		[4] 24	21.0	3.5	-31.2

[1] Gusts to 30
[2] " " 33
[3] " " 36
[4] " " 45

DATE: 3/28/77 | DATE: 3/29/77

TIME	3/28/77 SOUND LEVEL (AVERAGE dBA)	3/28/77 RAINFALL (INCHES)	3/28/77 WIND DIRECTION (FROM)	3/28/77 AVG. WIND SPEED (MPH)	3/28/77 AMBIENT TEMPERATURE (°C)	3/28/77 DEWPOINT (°C)	3/28/77 LOAD ON LINE (MW)	3/29/77 SOUND LEVEL (AVERAGE dBA)	3/29/77 RAINFALL (INCHES)	3/29/77 WIND DIRECTION (FROM)	3/29/77 AVG. WIND SPEED (MPH)
0100	51	0.01		[2] 20	20.5	4.5	-39.2	40	0		12
0200	52	0.01		21	20.5	4.5	-43.3	40	0		12
0300	51	0		22	20.0	7.5	-48.2	39	0		11
0400	51	0		23	20.0	9.0	-36.1	39	0		8
0500	54	0		25	19.5	10.0	-13.2	38	0		3
0600	55	0		25	19.5	10.5	17.7	40	0		5
0700	57	<0.01		[3] 25	19.0	11.5	63.4	44	0		1
0800	56	0.22		27	18.5	12.5	36.3	43	0		3
0900	59	0.10		13	14.0	12.0	30.8	44	0		3
1000	55	0.15		6	13.5	11.5	8.2	42	0		5
[illegible]0	54	0.22		[4] 10	13.5	11.5	7.4	43	0		9
1200	50	<0.01		[5] 15	14.5	11.5	19.0	45	0		12
1300	45	0		15	16.0	12.5	18.7	43	0.01		[7] 10
1400	45	0		15	17.5	11.5	26.5	43	0		[8] 13
1500	45	0		17	19.5	11.0	41.4	50	0.04		9
1600	45	0		15	20.0	10.5	52.0	55	0.07		6
1700	[1] 44	0		15	19.5	10.0	30.7	56	0.17		9
1800	42	0		13	18.0	9.5	9.2	55	0.11		15
1900	50	0		13	17.0	9.5	-26.1	54	0.07		10
2000	51	0		13	16.0	9.5	-40.5	52	<0.01		10
2100	49	0		15	15.5	10.0	-33.8	46	0		6
2200	45	0		[6] 13	15.5	10.5	-1.5	45	0	2130 2200	7 12
2300	42	0		15	16.0	11.5	24.1	43	0		13
2400	42	0		15	17.0	12.5	-9.9	44	0		[9] 19

[1] VERY HIGH WINDS PEAKED SOUND LEVEL @ 75dBA AT SOME POINTS

[2] GUSTS TO 46
[3] GUSTS TO >50
[4] " " 22
[5] " " 31
[6] " " 22

[7] GUSTS TO 18
[8] " " 20
[9] " " 31

DATE: 3/30/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (Average dBA)	Rainfall (Inches)	Wind Direction (From)	Avg Wind Speed (MPH)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
17.0	14.0	-55.0	43	0		14	22.0	19.5	-106.1
17.5	14.5	-66.1	[10] 50	<0.01		[11] 9	22.0	19.5	-112.5
18.0	15.5	-64.6	45	0.05		17	21.5	19.5	-105.7
18.5	16.5	-45.8	45	0.01		[12] 14	22.0	19.5	-84.2
17.5	15.5	-22.2	44	0		12	22.0	19.5	-86.0
16.5	15.0	-3.9	43	0		11	22.0	19.5	-48.9
16.5	15.0	14.6	42	0		10	22.0	19.5	-17.5
17.0	15.5	-43.9	42	0		10	22.5	20.0	-27.5
18.5	16.0	-63.9	44	0.01		9	21.5	19.5	-40.6
20.5	14.5	-60.9	43	0		11	22.0	19.5	-68.0
20.5	15.0	-58.7	43	0		14	22.5	19.5	-88.0
18.0	13.0	-8.5	41	0		[13] 12	23.5	20.0	-91.2
16.5	11.5	19.2	42	0		11	27.0	20.0	-91.2
18.0	12.5	15.9	41	0		10	26.5	19.5	-118.2
17.5	14.0	10.4	41	0		11	26.5	19.5	-137.8
16.5	14.5	17.2	40	0		8	27.5	20.0	-121.6
17.0	15.0	15.7	40	0		8	26.5	19.5	-127.0
17.0	15.0	1.0	40	0		8	25.0	19.0	-114.7
17.0	15.5	-42.3	52	0		6	24.0	20.0	-134.1
17.5	16.0	-78.4	51	0		7	23.0	20.0	-138.4
18.0	16.5	-85.2	49	0		5	22.5	20.0	-132.6
18.5	17.0	-60.5	45	0		6	22.5	19.5	-130.8
19.0	17.5	-49.4	42	0		5	22.0	17.0	-118.7
21.5	19.0	-81.4	40	0		3	20.0	14.5	-113.0

[10] @ 0130 @ peak of rainfall sound level averaged 61 dBA for approx. 4 minutes.

[11] Gusts to 20
[12] " " 27
[13] " " 22

TIME	DATE: 3/31/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	DATE: 4/1/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	40	Ø		0030 1 0100 11	19.5	12.5	−105.6	38	Ø		5
0200	38	Ø		10	18.5	7.5	−69.1	38	Ø		3
0300	40	Ø		[1]12	17.0	2.5	−53.9	38	Ø		2
0400	42	Ø		13	15.5	1.0	−48.8	38	Ø		2
0500	43	Ø		12	14.5	−1.0	−53.8	37	Ø		6
0600	41	Ø		6	13.0	−1.5	−4.8	40	Ø		7
0700	42	Ø		9	12.5	−1.0	45.1	42	Ø		5
0800	43	Ø		12	14.0	−1.5	37.3	45	Ø		[3]11
0900	43	Ø		12	15.0	−1.5	30.7	43	Ø		11
1000	41	Ø		8	16.0	−1.0	65.2	43	Ø		[4]15
[illegible]	42	Ø		7	17.0	−0.5	68.5	43	Ø		10
1200	41	Ø		7	18.0	0.5	69.1	45	Ø		[5]11
1300	42	Ø		7	20.0	1.0	77.8	49	0.03		12
1400	42	Ø		9	20.5	1.5	86.3	50	0.01		10
1500	42	Ø		[2]9	21.5	1.5	115.6	46	<0.01		[6]13
1600	42	Ø		8	21.5	1.5	131.6	44	0.01		10
1700	41	Ø		8	22.0	1.5	124.0	45	0.01		12
1800	43	Ø		8	19.5	2.5	114.6	50	Ø		12
1900	43	Ø		6	17.0	2.5	81.9	48	Ø		11
2000	43	Ø		5	15.0	3.0	64.0	46	Ø		12
2100	41	Ø		4	14.5	3.0	86.0	42	Ø		12
2200	40	Ø		4	14.0	3.0	69.9	41	Ø		12
2300	39	Ø		3	14.0	3.0	28.1	40	Ø		13
2400	39	Ø		3	14.0	3.0	84.0	39	Ø		12

[1] GUSTS TO 20
[2] " " 17

[3] GUSTS TO 22
[4] " " 24
[5] " " 20
[6] " " 20

DATE:

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
14.0	3.5	84.5							
12.5	4.0	92.8							
12.0	4.5	98.8							
11.5	6.0	118.8							
12.5	5.0	109.7							
12.0	5.0	148.3							
12.0	6.0	186.2							
13.0	6.0	130.9							
13.5	6.5	122.2							
14.0	8.0	125.9							
15.0	9.5	118.7							
15.0	10.5	115.5							
15.0	12.0	124.6							
14.0	12.0	81.3							
14.5	12.5	14.6							
14.5	12.5	6.6							
15.0	13.0	3.3							
15.0	13.0	16.9							
15.5	13.5	11.9							
16.0	14.0	12.8							
16.5	14.0	26.6							
16.5	14.0	-0.1							
16.5	14.0	-11.3							
16.5	14.0	-66.3							

DATE: 6/9/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100							
0200							
0300							
0400							
0500							
0600							
0700							
0800							
0900							
1000							
1100							
1200							
1300							
1400							
1500							
1600	40	0	NW	'11	33.5	15.0	-170.9
1700	39	0	NW	10	33.0	15.5	-142.6
1800	39	0	NW	7	31.5	16.5	-160.1
1900	39	0	NW	7	30.5	16.5	-138.8
2000	37	0	NW	4	29.0	16.0	-144.7
2100	38	0	NW	3	27.0	16.0	-141.4
2200	38	0	NW	3	24.0	16.0	-128.8
2300	36	0	NW	4	24.0	15.0	-103.6
2400	36	0	NW	4	23.5	12.5	-99.1

'GUSTS TO 19

DATE: 6/10/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	34	0		4
0200	34	0		5
0300	34	0		5
0400	34	0		4
0500	35	0		5
0600	40	0		5
0700	40	0		4
0800	40	0		6
0900	38	0		6
1000	40	0		6
1100	38	0		5
1200	38	0		4
1300	37	0		5
1400	37	0		6
1500	37	0		7
1600	38	0		7
1700	38	0		7
1800	36	0		7
1900	36	0		5
2000	39	0		2
2100	39	0		2
2200	39	0		3
2300	38	0		2
2400	35	0		2

DATE: 6/11/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (Average dBA)	Rainfall (Inches)	Wind Direction (From)	Avg. Wind Speed (MPH)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
22.5	9.5	-122.9	35	0		2	21.0	15.5	-124.8
21.5	8.0	-146.2	35	0		2	20.0	15.0	-118.1
21.0	7.5	-131.2	35	0		2	21.0	14.5	-107.3
20.0	7.5	-115.0	35	0		3	20.5	13.5	-93.7
20.0	8.0	-71.7	36	0		2	20.0	14.5	-94.2
19.5	8.0	4.9	42	0		1	19.0	14.5	-80.9
19.0	8.5	26.9	40	0		1	20.0	15.5	-61.7
20.5	9.5	35.1	38	0		2	22.5	16.5	-34.5
22.0	10.0	-5.2	38	0		4	28.0	15.0	-22.9
24.5	10.5	-78.9	38	0		5	30.0	14.5	-75.8
25.5	11.0	-122.8	38	0		5	31.5	16.5	-130.5
27.5	11.5	-172.1	37	0		9	33.5	17.5	-168.3
29.0	12.0	-138.9	38	0		10	35.0	18.5	-182.7
31.0	13.0	-152.8	36	0		10	36.0	19.0	-188.7
31.5	13.5	-217.5	35	0		8	37.0	19.0	-160.4
32.5	14.5	-237.3	35	0		7	37.5	18.5	-163.7
33.5	15.0	-233.1	38	0		11	37.5	17.5	-142.3
33.0	15.5	-198.1	38	0		10	37.5	18.0	-139.0
32.5	16.0	-163.6	40	0		7	36.0	18.5	-157.5
30.0	16.5	-130.8	42	0		6	34.5	18.0	-183.4
25.5	17.5	-140.1	40	0		2	29.5	19.0	-184.8
25.0	16.5	-185.1	42	0		2	27.5	19.5	-115.8
24.5	16.5	-148.7	42	0		2	26.5	19.5	-83.9
21.5	16.5	-122.6	42	0		2	25.5	20.0	-101.7

DATE: 6/12/77 DATE: 6/13/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	40	0		1	25.5	20.0	-61.4	39	0		2
0200	39	0		2	25.5	20.0	-69.4	38	0		4
0300	38	0		2	24.5	20.0	-67.9	38	0		3
0400	38	0		3	24.0	20.0	-128.8	37	0		2
0500	38	0		5	25.5	19.5	-148.0	39	0		3
0600	43	0		4	25.5	19.0	-142.9	40	0		3
0700	40	0		5	26.5	19.5	-88.0	41	0		4
0800	40	0		5	26.5	19.5	-22.4	41	0		7
0900	39	0		7	28.0	20.0	18.7	38	0		8
1000	38	0		8	30.0	19.5	18.0	40	0		7
1100	38	0		9	32.5	19.0	7.2	37	0		7
1200	40	0		[1] 15	35.0	17.0	-9.9	38	0		7
1300	41	0		[1] 15	36.5	16.0	-14.3	40	0		6
1400	40	0		14	37.0	15.5	-35.0	37	0		4
1500	40	0		13	37.5	15.0	-49.3	37	0		8
1600	38	0		12	37.5	15.5	-54.2	39	0		8
1700	38	0		11	37.5	15.5	-62.0	40	0		9
1800	38	0		9	37.5	15.0	-55.7	40	0		9
1900	37	0		5	36.5	15.5	-70.0	[2] 43	0.02		[3] 20
2000	38	0		4	33.0	17.0	-93.5	49	0.03		[4] 12
2100	40	0		3	28.5	18.0	-79.9	40	0		5
2200	40	0		2	26.0	18.5	-69.0	40	0		4
2300	39	0		2	25.5	18.0	-62.9	39	0		4
2400	38	0		2	25.0	18.0	-41.6	39	0		6

[1] Gusts to 23

[2] Sound level averaged 55dBA for approx. 3 minutes during peak of rainfall.

[3] Gusts to 38

[4] " " 27

DATE: 6/14/77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
25.5	18.5	-9.5	39	0		5	23.0	20.5	-33.1
29.5	18.0	-9.6	39	0		2	23.0	21.0	-26.8
26.5	18.0	-40.3	38	0		0	22.5	20.5	-25.4
24.5	18.0	-54.6	38	0		3	22.5	20.5	-30.5
23.5	17.5	-49.2	39	0		0	22.5	21.0	-11.3
25.5	17.0	-10.0	41	0		6	22.5	20.5	33.9
25.5	18.0	29.1	39	0		6	22.5	21.0	27.9
26.5	18.5	25.5	40	0		6	23.5	21.5	-35.6
28.5	20.0	-51.9	41	0		3	25.0	21.5	-80.6
30.0	21.0	-134.2	40	0		7	26.5	20.5	-106.6
31.5	21.5	-163.9	41	0		9	27.5	20.5	-121.0
34.0	21.0	-184.8	38	0		8	29.0	20.5	-118.5
35.0	20.5	-157.8	41	0		8	30.0	20.0	-84.4
35.0	21.5	-159.8	39	0		8	30.0	20.5	-128.6
37.0	18.5	-197.5	40	0		10	30.5	20.5	-172.4
37.5	17.5	-220.6	40	0		11	30.0	20.5	-213.7
37.0	18.0	-228.6	40	0		10	30.0	20.0	-199.3
36.0	18.5	-221.2	41	0		7	29.5	20.5	-210.5
31.0	18.0	-190.4	40	0		6	28.0	21.0	-186.7
26.0	17.5	-138.3	40	0		6	27.0	20.5	-157.9
23.5	20.5	-134.0	40	0		3	26.0	20.5	-160.6
23.0	19.5	-160.0	41	0		2	25.5	20.0	-128.6
23.5	20.0	-73.8	41	0		3	25.0	20.0	-68.6
23.0	20.5	-18.0	40	0		1	24.5	20.0	-17.7

TIME	DATE: 6/15/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	DATE: 6/16/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	39	0		0	23.5	20.0	-3.4	40	0		0
0200	37	0		0	23.0	20.0	-21.0	41	0		5
0300	37	0		0	22.5	20.0	-25.9	40	0		6
0400	37	0		0	22.0	20.0	-44.2	39	0		6
0500	36	0		0	22.0	20.0	-31.3	37	0		6
0600	41	0		0	21.5	20.0	44.0	43	0.01		6
0700	46	0		0	21.5	20.0	40.4	52[1]	<0.01		0
0800	40	0		3	22.5	20.5	-15.0	46	0		2
0900	39	0		4	23.5	21.0	-101.4	42	0.01		2
1000	40	0		6	25.0	20.5	-156.6	44	0		2
1100	44	0		7	26.0	19.5	-197.1	42	0		3
1200	40	0		7	27.0	19.5	-205.0	42	0		4
1300	39	0		7	28.0	19.5	-190.5	42	0		5
1400	48	0.01		5	26.5	20.0	-199.9	41	0		3
1500	42	0		4	25.5	21.5	-225.4	42	0		4
1600	40	0		5	27.0	21.0	-244.3	43	0		4
1700	40	0		6	28.5	20.5	-242.9	41	0		5
1800	39	0		6	28.5	20.0	-253.4	43	0		5
1900	40	0		5	27.5	19.5	-208.6	45	0		4
2000	40	0		2	26.0	19.5	-151.5	45	0		3
2100	40	0		1	24.5	20.0	-135.2	42	0		3
2200	42	0		0	24.5	20.0	-125.0	44	0		2
2300	41	0		0	24.0	20.0	-113.4	44	0		0
2400	41	0		0	24.0	20.0	-89.0	42	0		1

[1] Sound level averaged 55 dBA for several minutes during rainfall.

DATE: 6/17/77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
24.0	20.0	-56.7	41	0		3	25.0	20.0	-29.4
23.5	20.0	-60.4	40	0		1	23.0	20.0	-21.4
23.0	20.0	-62.4	40	0		2	22.5	20.0	6.8
22.5	20.0	-78.5	39	0		1	23.0	20.0	4.3
22.0	20.0	-74.9	38	0		3	23.5	20.0	10.6
22.0	20.0	-25.4	44	0		3	24.0	20.0	19.1
22.5	20.5	-26.7	43	0		3	24.5	20.0	-2.6
23.0	21.5	-75.8	45	0		3	25.5	20.0	-14.4
24.5	22.5	-125.6	43	0		5	27.5	20.5	-75.1
25.0	22.5	-90.8	44	0		6	29.0	21.0	-106.1
26.0	22.5	-129.7	44	0		6	30.5	21.5	-137.1
26.5	22.0	-158.9	41	0		6	32.0	21.0	-177.3
28.5	21.0	-122.9	42	0		9	33.0	21.5	-151.5
29.5	20.5	-130.1	45	0.30		10	32.0	21.5	-178.4
29.5	20.5	-189.1							
30.0	20.5	-200.9							
31.0	20.5	-216.4							
30.5	20.0	-235.5							
30.0	20.0	-207.5							
28.5	20.0	-198.0							
26.0	20.5	-170.7							
25.0	20.0	-188.8							
25.0	20.0	-121.2							
25.5	20.0	-54.4							

	DATE: 7/30/77							DATE: 7/31/77			
TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AV. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AV. WIND SPEED (MPH)
0100								48	0		0
0200								48	0		0
0300								47	0		0
0400								48	0		0
0500								50	0		0
0600								50	0		0
0700								50	0		0
0800								48	0		0
0900								46	0		0
[illegible]								45	0	SW	3
1100								44	0	SW	4
1200								43	0	W-SW	3
1300								42	0	SW	4
1400								40	0		0
1500								41	0		0
1600	39	0	SW	2	33.5	22.5	-235.9	43	0		0
1700	40	0	SW	1	33.5	22.5	-235.9	40	0	SW	5
1800	41	0	SW	1	32.0	23.0	-238.8	42	0	SW	5
1900	42	0	NW	1	29.5	23.0	-188.8	40	0		0
2000	45	0	W-SW	7	28.5	23.0	-190.2	41	0		0
2100	46	0		0	27.5	23.0	-201.7	45	0		0
2200	48	0		0	26.5	23.0	-137.0	46	0		0
2300	47	0		0	26.0	23.0	-88.6	46	0		0
2400	47	0		0	25.5	23.0	-69.7	46	0		0

DATE: 8/1/77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
25.0	22.5	- 52.8	46	0		0	24.0	21.5	- 66.7
24.0	22.0	- 57.9	44	0		0	23.0	20.5	- 58.8
24.0	22.0	- 54.2	45	0		0	22.5	20.5	- 50.2
23.5	22.5	- 54.5	44	0		0	22.5	20.0	- 60.0
23.0	21.0	- 52.8	44	0		0	22.5	20.5	- 48.0
23.0	21.0	- 53.6	46	0		0	22.0	20.0	- 37.1
23.0	21.0	- 37.2	47	0		0	22.5	21.0	- 35.3
23.5	21.5	6.7	51	0		0	23.0	21.5	- 75.1
24.5	22.0	7.9	46	0		0	23.5	22.0	- 141.1
26.0	22.0	- 23.0	45	0		0	25.0	21.5	- 228.4
27.5	22.5	- 53.7	44	0	NW	3	27.0	21.5	- 252.0
29.5	22.5	- 69.4	42	0	NW	2	30.0	22.0	- 283.6
30.0	22.5	- 116.4	39	0	NW	4	31.5	22.5	- 310.8
31.0	22.5	- 148.6	38	0		0	33.0	22.0	- 350.7
32.5	22.5	- 152.4	37	0		0	34.0	21.5	- 391.2
30.5	22.5	- 177.7	40	0	N-NW	1	34.0	21.0	- 401.7
28.0	23.5	- 162.4	40	0		0	33.5	21.0	- 442.5
26.0	22.5	- 145.6	43	0	N-NW	4	33.0	21.5	- 440.3
26.0	22.0	- 136.0	42	0	N-NW	3	32.5	21.0	- 385.4
26.0	22.0	- 134.2	43	0		0	30.5	21.5	- 359.1
24.5	21.5	- 137.2	45	0	N-NW	1	28.5	20.5	- 358.8
24.0	21.5	- 137.2	46	0	N	2	28.0	20.5	- 351.8
24.0	21.0	- 132.3	46	0	N	2	27.0	21.0	- 264.7
24.0	21.5	- 62.3	46	0	N-NE	2	27.0	21.0	- 199.0

TIME	DATE: 8/2/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	DATE: 8/3/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	46	0	N-NE	2	26.0	21.0	- 178.6	41	0		
0200	45	0	N	2	26.0	21.0	- 141.7	40	0		
0300	45	0	N	2	25.0	21.0	- 120.7	39	0		
0400	45	0	N-NE	2	24.5	20.5	- 112.1	40	0		
0500	45	0	N-NE	3	23.5	19.0	- 100.1	40	0		
0600	45	0	NE	2	23.5	18.5	- 101.1	41	0		
0700	46	0	N	2	23.0	18.5	- 108.6	42	0		
0800	44	0	N	4	24.0	19.5	- 159.3	37	0		
0900	44	0	N	4	25.5	20.0	- 236.5	42	0		
1000	46	0	N	2	28.0	21.5	- 326.6	44	0		
1100	43	0	E-SE	1	30.5	22.0	- 367.0	44	0		
1200	40	0	SE	2	32.5	21.0	- 397.5	45	0		
1300	38	0	N-NW	1	33.0	20.5	- 373.8	41	0		
1400	38	0	S-SE	2	34.0	20.5	- 385.5	39	0		
1500	37	0	S	2	34.5	20.0	- 390.1	40	0		
1600	39	0	SW	3	34.5	20.5	- 360.3	40	0		
1700	43	0	W-SW	3	34.0	21.0	- 335.1	41	0		
1800	46	0	SE	19	28.5	17.5	- 311.3	42	0		
1900	45	0	S	9	26.5	17.0	- 287.8	42	0		
2000	40	0			24.5	17.0	- 242.7	43	0		
2100	40	0			24.5	19.0	- 240.2	40	0		
2200	42	0			23.5	19.0	- 223.1	38	0		
2300	42	0			22.5	19.0	- 171.1	37	0		
2400	41	0			22.5	19.0	- 151.4	36	0		

DATE: 8/22/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (Average dBA)	Rainfall (inches)	Wind Direction (From)	Av. Wind Speed (MPH)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
22.5	19.0	- 130.3	46	0	S-SE	6	25.0	20.5	- 237.1
22.5	19.0	- 127.5	46	0	E-NE	6	23.5	20.0	- 266.6
21.5	19.0	- 135.2	44	0	E	7	23.0	20.0	- 233.9
22.0	19.5	- 151.5	41	0	E-SE	7	22.5	20.0	- 223.0
22.0	19.5	- 125.8	40	0	E	7	21.5	19.5	- 206.0
22.0	19.5	- 90.4	40	0	E	5	21.5	19.0	- 154.7
21.5	19.5	- 53.2	43	0	E	4	21.5	19.0	- 130.0
23.5	20.0	- 85.1	46	0	W	3	22.5	21.0	- 142.5
25.0	20.5	- 141.3	49	0	NW	3	25.0	22.0	- 203.0
25.0	20.5	- 198.5	50	0	N	3	27.5	21.5	- 264.8
26.0	20.5	- 222.0	49	0	N	3	30.0	21.5	- 334.1
27.0	20.5	- 216.3							
28.5	21.0	- 195.7							
30.0	20.5	- 216.8							
31.0	20.0	- 226.4							
32.0	20.0	- 247.3							
32.5	20.0	- 279.1							
32.5	20.0	- 247.3							
31.5	20.5	- 243.2							
29.0	21.0	- 204.1							
27.5	21.0	- 184.4							
26.0	21.0	- 175.0							
25.0	21.0	- 127.3							
25.0	20.5	- 38.1							

DATE: 8/23/77 | DATE: 8/24/77

TIME	8/23/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	8/24/77 SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)
0100											
0200											
0300											
0400											
0500											
0600											
0700											
0800											
0900											
1000											
[illegible]								39	0	NW	7
1200								40	0	WNW	3
1300								37	0	W-NW	4
1400	42	0	SE	10	35.0	22.0	- 305.9	37	0	SW	3
1500	41	0	SW	10	35.0	21.5	- 265.4	39	0	SW	3
1600	'39	0	SE	8	30.5	21.5	- 290.2	42	0	SW	5
1700	39	0	E	3	27.5	21.0	- 301.4	41	0	SW	3
1800	1730 44 1800 60	0.06	E-SE	3	28.0	21.5	- 302.3	40	0	E-SE	4
1900								47	0	E	3
2000								45	0	NE	4
2100								46	0	W	5
2200								46	0	SE	7
2300								44	0	SE	8
2400								43	0	NE	8

'For a period of approx. 5 minutes just before 1600 the sound level averaged 63 dBA (w/ peaks to 73 dBA). The reason is unknown.

DATE: 8/25/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (Average dBA)	Rainfall (inches)	Wind Direction (from)	Avg. Wind Speed (mph)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
			43	0	E	8	24.0	21.5	-166.2
			44	0	N	8	23.5	21.5	-153.5
			43	0	SE	7	23.5	21.5	-176.0
			40	0	E-SE	9	23.5	21.5	-180.0
			46	0	NE	9	23.0	21.0	-140.3
			43	0	E	4	23.0	20.5	-13.0
			43	0	E	2	23.5	21.0	111.0
			43	0	E	3	24.0	21.5	125.0
			43	0	E	4	25.0	22.0	100.7
			44	0	SE	7	27.0	22.5	34.9
31.0	23.5	-[illegible]	43	0	SE	6	29.5	23.0	-3.6
32.5	23.0	-294.2	41	0	SE	7	32.5	23.5	-52.8
34.0	22.0	-313.4	39	0	SE	7	33.5	24.0	-37.2
35.0	22.0	-305.9	39	0	S	7	33.0	23.5	-24.4
35.0	22.0	-265.4	41	0	S-SW	8	32.5	23.5	-43.3
34.5	22.0	-290.2	39	0	SW	5	34.0	24.0	-37.8
34.0	22.5	-301.4	47	0	SW	4	33.5	24.0	-34.3
30.0	21.0	-302.3	44	0	E-SE	6	30.0	23.5	14.0
29.0	20.5	-285.1	46	0	SE	6	29.5	25.0	12.4
27.0	20.5	-273.6	46	0	E	7	28.0	25.0	48.9
26.0	21.5	-279.2	45	0	NE	7	27.5	25.0	34.5
26.5	22.0	-259.1	44	0	E	5	27.5	24.0	-16.6
26.5	21.5	-234.1	44	0	E-SE	5	27.0	23.0	59.7
25.0	22.0	-178.6	44	0	SE	6	26.5	22.0	108.9

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DATE: 8/26/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100	44	θ	SE	8	26.0	22.0	127.1
0200	44	θ	SE	6	26.0	22.0	119.2
0300	44	θ	SE	7	25.5	22.0	95.8
0400	43	θ	SE	8	25.0	22.0	70.6
0500	44	θ	SE	[1]10	24.5	21.5	63.2
0600	46	θ	SE	4	25.0	22.0	156.8
0700	44	θ	SE	3	25.0	22.0	208.9
0800	44	θ	SE	4	26.0	22.5	193.3
0900	43	θ	S-SE	[2]9	26.0	23.0	153.3
1000							
1100							
1200							
1300							
1400							
1500							
1600							
1700							
1800							
1900							
2000							
2100							
2200							
2300							
2400							

[1] Gusts to 21
[2] " " 17

DATE: 8/30/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
1500	42	θ		
1600	39	θ		
2200	47	θ		
2300	47	θ		
2400	46	θ		
	46	θ		

DATE: 8/31/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (average dBA)	Rainfall (inches)	Wind Direction (from)	Av. Wind Speed (mph)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
			45	0	E-SE	5	26.0	17.0	24.0
			45	0	E-SE	5	25.5	17.0	18.1
			43	0	E-SE	4	25.5	16.5	- 3.5
			42	0	E-SE	4	25.0	16.5	- 42.3
			41	0	E-SE	7	25.0	17.0	- 76.7
			43	0	SE	10	25.0	17.0	9.8
			47	0	SE	9	25.0	17.0	84.4
			47	0	SE	8	26.0	18.0	79.8
			45	0	E-SE	10	28.0	19.5	10.6
			44	0	E-SE	10	30.0	19.5	- 83.1
			43	0	E-SE	11[3]	31.5	19.5	- 174.0
			42	0	E-SE	12[4]	33.5	19.5	- 181.7
33.0			39	0	E	10	33.5	18.5	- 171.5
34.5		- 72.7	35	0	E	15[5]	34.0	18.5	- 180.9
		- 108.2	<30	0	E	11	35.0	18.0	- 185.4
			<30	0	E-SE	10	35.0	17.0	- 182.1
			<30	0	E-SE	10	35.0	16.0	- 215.8
			<30	0	SE	8	35.0	16.5	- 222.2
			<30	0	SE	5	34.5	17.0	- 223.6
28.0			38	0	E-SE	5	29.0	18.0	- 178.3
28.0		- 137.6	48	0	E-SE	5	26.0	18.0	- 162.4
27.0		- 140.6	50	0	E-SE	5	26.0	18.0	- 137.2
26.0		- 99.6	49	0	SE	6	26.5	18.5	- 54.5
		- 27.5	47	0	SE	6	26.5	18.5	- 31.9

[3] Gusts to 22
[4] " - 23
[5] " " 24

DATE: 9/1/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100	46	Ø	E-SE	5	26.0	17.5	- 26.4
0200	44	Ø	SE	5	26.0	17.0	- 29.9
0300	44	Ø	E-SE	5	25.5	17.5	- 33.4
0400	45	Ø	E-SE	5	26.5	18.0	- 62.7
0500	43	Ø	E-SE	7	25.5	17.5	- 39.0
0600	45	Ø	E-SE	7	25.0	17.5	- 23.9
0700	47	Ø	SE	8	25.0	17.5	- 17.5
0800	48	Ø	E-SE	7	26.0	19.0	- 19.3
0900	47	Ø	E-SE	9	28.0	20.0	- 36.9
1000	44	Ø	E-SE	9	29.5	20.0	- 90.9
1100	43	Ø	E	10	31.0	20.0	- 118.9
[illegible]	43	Ø	E-NE	[1]12	31.5	19.0	- 196.0
1300	40	Ø	E	13	33.0	18.5	- 215.1
1400	<30	Ø	E	12	33.5	18.0	- 197.3
1500	<30	Ø	E	11	34.5	17.5	- 204.5
1600	<30	Ø	E	12	35.0	17.5	- 188.1
1700	<30	Ø	E	10	34.5	18.0	- 174.7
1800	<30	Ø	E	9	34.0	17.5	- 179.2
1900	<30	Ø	E	5	32.5	17.5	- 192.4
2000	<30	Ø	E-SE	4	28.5	18.0	- 124.6
2100	45	Ø	SE	4	26.5	18.5	- 169.5
2200	51	Ø	SE	5	25.0	19.0	- 139.8
2300	48	Ø	E-SE	6	25.5	18.0	- 11.8
2400	47	Ø	E-SE	5	25.5	19.0	55.5

[1] GUSTS TO 22

DATE: 9/2/77

SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
44	Ø	E-SE	4
43	Ø	E-SE	5
43	Ø	E-SE	5
42	Ø	E-SE	3
41	Ø	NE	3
41	Ø	E-SE	2
43	Ø	E-SE	3
45	Ø	E-NE	4
47	Ø	NE	5
46	Ø	E-NE	7
44	Ø	E	[2]11
42	Ø	E	[3]14
39	Ø	E	13
39	Ø	E-NE	[2]11
40	Ø	E	[3]12
39	Ø	E	12
39	Ø	E	11
42	Ø	E	9
42	Ø	E	6
45	Ø	E-SE	5
52	Ø	E-SE	5
51	Ø	E-SE	4
49	Ø	E-SE	1
47	Ø	E	3

[2] GUSTS TO 21
[3] " " 23

DATE: 9/3/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (average dBA)	Rainfall (inches)	Wind Direction (from)	Avg. Wind Speed (mph)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
25.0	19.0	85.5	46	0	NE	3	24.0	21.5	47.5
24.5	19.5	67.3	46	0	NE	2	23.5	21.5	28.3
24.5	19.0	69.8	43	0	NE	1	22.0	21.0	37.3
24.5	19.5	74.5	43	0	E	3	21.5	21.0	26.0
22.5	19.5	75.2	47	0	NE	3	22.0	21.0	23.8
21.5	20.0	113.0	47	0	NE	3	21.5	21.0	33.7
20.5	20.5	172.8	47	0	E	3	20.5	20.5	48.3
23.0	20.5	171.5	49	0	NE	4	22.5	21.0	75.8
27.0	21.0	94.1	49	0	E	4/10	26.5	21.5	81.7
29.5	21.0	5.1	49	0	E	10	28.5	22.5	89.6
31.0	22.0	-54.9	48	0	E	5/15	30.0	22.5	40.8
31.5	22.0	-93.7	46	0	E-NE	5/16	32.0	22.0	3.6
33.0	22.5	-85.6	44	0	E-NE	15	33.0	22.5	-3.4
33.5	22.5	-64.6	43	0	E	15	34.0	22.5	3.7
34.5	22.0	-92.3	43	0	E-NE	14	34.5	21.5	-6.8
35.0	22.0	-89.7	43	0	E	14	35.0	21.5	-.8
35.0	22.5	-58.5	43	0	E	10	35.0	21.0	-21.3
34.5	22.0	-86.1	43	0	E-SE	10	34.5	21.5	-30.3
33.0	22.0	-74.9	39	0	E-SE	7	33.0	21.5	-55.3
29.5	21.5	-51.1	45	0	E-SE	7	30.5	21.0	-148.8
27.5	21.0	-72.5	53	0	SE	7	29.0	21.5	-223.5
25.5	21.5	-53.2	51	0	SE	6	28.0	21.5	-204.4
24.5	21.5	23.7	52	0	E-SE	6	26.5	21.5	-232.2
24.0	21.5	37.7	51	0	E-SE	9	27.0	21.5	-223.8

4 Gusts to 19
5 " " 25

DATE: 9/4/77 | DATE: 9/5/77

TIME	Sound Level (Average dBA)	Rainfall (Inches)	Wind Direction (From)	Avg Wind Speed (MPH)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (Averaged BA)	Rainfall (Inches)	Wind Direction (From)	Avg Wind Speed (MPH)
0100	50	Ø	E-SE	7	27.0	21.0	-223.7	49	Ø	E-SE	7
0200	50	Ø	E-SE	9	26.5	20.5	-220.6	48	Ø	E-SE	4
0300	50	Ø	E-SE	9	26.0	20.5	-243.0	44	Ø	E-NE	3
0400	48	Ø	E-SE	7	25.5	20.0	-196.6	43	Ø	SE	4
0500	45	Ø	E	4	25.0	20.0	-192.4	46	Ø	E-SE	4
0600	50	0.02	E-NE	3	24.0	20.0	-187.5	47	Ø	E-SE	5
0700	56	0.03	E-NE	4	23.5	20.0	-186.0	48	Ø	E-NE	3
0800	54	<0.01	E	6	23.5	20.0	-157.7	47	Ø	E	7
0900	46	0.02	E	8	24.0	20.5	-165.8	47	Ø	E-NE	7
1000	0920 46 1000 55	0.06	E	7	24.0	21.0	-186.3	47	Ø	SE	7
[illegible]0	1020 52 1100 47	<0.01	E	9	24.5	21.5	-164.6	46	Ø	SE	6
1200	47	0.01	E	8	25.5	22.5	-160.4	45	Ø	SE	8
1300	[1] 47	<0.01	E	4	25.5	22.5	-181.0	46	0.01	SE	8
1400	44	Ø	E	8	26.5	22.5	-202.0	43	Ø	E-SE	8
1500	42	Ø	E	10	27.5	22.5	-204.4	43	Ø	SE	7
1600	43	Ø	E-NE	10	28.0	22.5	-183.3	40	Ø	S-SE	8
1700	42	Ø	E	10	29.0	22.5	-208.5	41	Ø	SE	6
1800	41	Ø	E-NE	9	28.5	22.0	-211.6	39	Ø	S	5
1900	40	Ø	E-NE	8	28.0	21.5	-203.6	41	Ø	S-SE	5
2000	45	Ø	E-NE	6	26.5	21.5	-191.5	45	Ø	S	6
2100	52	Ø	E-NE	7	26.0	21.5	-208.3	52	Ø	S-SE	4
2200	52	Ø	E	4	26.0	21.5	-202.9	51	Ø	SE	3
2300	51	Ø	E	4	25.0	22.0	-215.2	49	Ø	E-SE	3
2400	50	Ø	E	5	25.0	22.0	-218.9	49	Ø	E-SE	4

[1] Sound level averaged 55dBA for about 18 minutes @ end of rainfall.

DATE: 9/6/'77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
25.0	22.0	- 243.9	49	0	E-SE	6	25.0	20.0	- 267.6
25.0	22.0	- 251.4	48	0	E-SE	5	24.0	22.0	- 265.1
24.5	22.0	- 242.1	48	0	E-SE	7	24.0	19.5	- 270.5
24.0	22.0	- 248.4	48	0	E-SE	6	24.5	19.5	- 241.5
24.0	22.0	- 243.3	47	0	E-SE	6	24.5	19.0	- 217.6
24.0	22.0	- 229.0	46	0	E-SE	5	24.5	19.0	- 172.5
23.5	22.0	- 289.9	46	0	E	5	24.5	19.5	- 163.1
24.5	22.0	- 269.7	44	0	E-SE	7	24.5	20.0	- 181.0
26.0	22.0	- 220.3	55	0.02	E-SE	7	25.0	20.5	- 221.1
28.0	22.5	- 248.8	49	0.05	E-SE	9	24.5	21.0	- 247.1
29.5	23.5	- 237.6	44	0	E-SE	10	25.0	22.0	- 267.0
30.0	23.5	- 227.3	44	0	E	[2]12	25.0	21.5	- 285.9
31.0	23.0	- 254.5	44	0	E	13	25.5	22.5	- 235.6
31.0	22.0	- 267.3	46	0	E	15	26.5	22.0	- 209.5
31.5	21.5	- 275.9	45	0.01	E	13	26.5	21.5	- 182.4
31.5	21.0	- 288.7	45	0.04	E	[3]11	26.0	21.5	- 115.0
31.0	21.5	- 287.9	44	0.10	E	13	26.0	21.5	- 205.1
30.5	21.5	- 299.8	55	0.12	E-SE	[4]15	25.0	21.5	- 219.4
29.5	21.5	- 278.5	55	0.02	E	11	24.5	20.5	- 232.6
28.5	21.5	- 250.8	54	0.25	E	15	24.5	21.0	- 213.2
27.0	21.5	- 257.3	55	0.25	E	15	24.5	20.5	- 271.1
26.5	21.0	- 300.4	60	0.25	E	17	24.5	20.5	- 248.5
25.0	21.0	- 280.1	58	≈0.70	E	16	24.5	20.0	- 222.5
25.0	20.5	- 270.5	57	1.50	E	19	24.5	20.0	- 192.0

[2] Gusts to 21
[3] " " 19
[4] " " 30

8406040266-22

	DATE: 9/7/77							DATE: 9/8/77			
TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	64	0.79	E-NE	20	24.0	19.5	- 175.1	46	Ø		
0200	55	0.19	E	14	24.0	19.0	- [illegible]	43	Ø		
0300	54	0.50	E-SE	13	24.0	19.0	- 180.8	44	Ø		
0400	56	0.25	E	13	23.5	18.5	- 185.5	45	Ø		
0500	54	0.11	S	9	24.0	18.5	- 152.7	44	Ø		
0600	52	0.06	S	0530 11, 0600 1	24.0	18.0	- 106.7	48	Ø		
0700	52	0.02	S	1	24.0	18.0	- 106.1	48	Ø		
0800	51	0.03		Ø	24.0	20.5	- 101.5	48	Ø		
0900	50	Ø		Ø	24.0	22.5	- 56.0	48	Ø		
1000	50	0.09		Ø	24.5	22.0	- 18.4	49	Ø		
1100	48	Ø		Ø	25.0	22.0	35.5	46	Ø		
1200	44	Ø		Ø	25.5	21.5	33.4	44	Ø		
1300	44	0.02		Ø	25.0	21.5	23.8	42	Ø		
1400	1330 43[1], 1400 54	0.02		Ø	24.5	21.5	30.6	42	Ø		
1500	52	Ø		Ø	23.5	21.5	84.3	42	Ø		
1600	51	0.01		Ø	23.0	21.5	67.8	43	Ø		
1700	53	Ø		Ø	23.0	22.0	67.2	41	Ø		
1800	45	Ø		Ø	23.0	22.0	61.7	40	Ø	N-NW	2
1900	41	Ø		Ø	23.0	22.0	49.2	41	Ø	NE	3
2000	45	Ø		Ø	23.5	22.5	48.6	45	Ø	E-SE	2
2100	49	Ø		Ø	23.5	22.0	23.5	49	Ø	E-SE	2
2200	50	Ø		Ø	24.0	22.0	- 1.6	47	Ø	E-SE	3
2300	48	Ø		Ø	23.5	21.5	42.1	46	Ø	E-SE	2
2400	47	Ø		Ø	23.5	21.5	- 3.3	46	Ø	SE	2

[1] Sound level increased abruptly when rain re-commenced @ 1320 fr. 43 to 54 dBA.

DATE: 9.19.77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (average dBA)	Rainfall (inches)	Wind Direction (from)	Avg. Wind Speed (mph)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
22.5	22.0	-41.9	45	0	E-SE	2	22.0	19.0	-45.2
22.0	22.0	-11.5	44	0	E-SE	2	21.5	19.0	-47.9
21.5	21.5	23.6	43	0	E	1	21.0	18.5	-53.0
21.5	21.0	48.0	43	0	E	2	20.5	18.5	-49.8
21.5	21.0	73.3	44	0	E	2	20.5	18.0	-22.7
21.0	21.0	103.3	47	0	E	2	21.0	17.5	33.6
21.0	21.0	135.7	50	0	E	2	20.0	16.5	41.3
21.5	21.5	113.4	49	0	NE	2	22.0	16.0	101.8
22.5	21.5	60.1	48	0	SE	2	25.0	16.5	73.9
24.5	21.5	15.5	47	0	S	5	28.0	17.0	47.0
26.0	22.0	-13.2	45	0	S-SW	6	29.5	16.5	65.5
27.5	21.5	-34.2	45	[illegible]	SW	7	31.0	14.0	15.7
29.0	21.5	-31.1	[illegible]	0	SW	7	31.5	14.0	3.5
30.0	21.5	-53.9	[illegible]	0	SW	7	32.5	14.0	-1.1
30.5	20.5	-51.3	[illegible]	0	SW	6	33.0	13.5	1.8
31.5	20.0	-7.9	[illegible]	0	SW	6	33.0	12.5	10.6
31.0	21.0	-5.3	43	0	SW	5	31.5	12.0	6.4
31.0	21.0	-4.4	44	0	SW	7	30.5	12.5	38.1
29.5	19.5	-10.5	42	0	SW	5	29.0	15.0	36.3
25.5	19.5	-12.3	45	0	SW	5	27.5	16.0	25.8
23.5	19.5	-46.9	50	0	SW	5	27.5	15.5	4.9
23.5	20.0	-38.6	48	0	S	3	25.5	13.5	8.0
22.5	19.5	-30.4	47	0	E	3	24.5	13.5	31.8
22.5	19.0	-81.2	47	0	S	1	24.5	12.5	26.4

DATE: 9/10/77 | DATE: 9/11/77

TIME:	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)
0100	47	0	S	3	25.0	12.5	14.3	44	0	N	2
0200	48	0	SW	4	25.0	12.5	.1	43	0	N	2
0300	47	0	SW	3	24.5	12.0	20.3	43	0	N	3
0400	47	0	W-SW	4	24.5	11.5	47.6	44	0	N	2
0500	47	0	W	3	24.0	11.5	82.5	45	0	NE	2
0600	47	0	W-SW	2	24.0	11.5	112.8	45	0	N-NE	3
0700	47	0	S	2	23.5	11.5	138.4	47	0	N-NE	4
0800	47	0	SW	3	23.5	13.0	215.5	47	0	N	6
0900	46	0	W	6	25.0	13.5	187.6	48	0	N	8
1000	46	0	W	8	25.5	15.0	106.4	47	0	N	8
1100	44	0	W-NW	5	27.0	15.5	69.2	45	0	N	9
1200	43	0	N-NW	11*	28.5	17.5	11.6	44	0	N	10
1300	42	0	N-NW	6	29.5	18.5	-12.3	40	0	N	10
1400	42	0	NW	8	30.5	19.5	-11.5	39	0	N	9
1500	41	0	W-NW	9	31.0	20.0	-23.1	39	0		9
1600	39	0	W	6	31.5		-8.2	39	0		8
1700	40	0	W-SW	7	32.0		-39.5	39	0		8
1800	40	0	NW	8	31.0		-48.2	42	0		6
1900	39	0	N	6	27.5		-23.3	40	0		2
2000	48	0	N	4	26.0		-35.8	45	0		3
2100	49	0	S	4	24.5		-48.3	47	0		[illegible]
2200	48	0	SE	2	23.0		10.3	46	0		3
2300	46	0	N	1	22.5		50.4	45	0		3
2400	46	0	N	3	22.0		8.1	44	0		2

*Gusts to 22

DATE: 9/12/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (average dBA)	Rainfall (Inches)	Wind Direction (From)	Avg Wind Speed (MPH)	Ambient Temperature °C	Dewpoint (°C)	Load on Line (MW)
22.0		-17.2	43	0		4			-42.6
22.0		-20.2	41	0		2			-37.0
21.5		14.7	42	0		6			-30.1
21.0		30.7	41	0		6			-34.3
21.0		13.9	41	0		4			-16.1
20.0		-2.9	42	0		3			21.0
19.5		8.4	43	0		3			36.5
19.5		87.0	47	0		5			57.2
22.0		137.4	47	0		10			57.3
24.0		151.9	48	0		[2]13			23.8
26.0		169.1	47	0		11			-4.4
27.5		138.6	45	0		12			-26.9
28.0		112.3	41	0		12			-39.3
29.0		87.5	38	0		8			-75.8
30.0		86.0	38	0	S	8	32.0	20.0	-46.0
30.0		81.4	41	0	S	7	31.5	20.5	-71.0
29.5		29.3	40	0	S-SE	5	31.0	20.5	-75.9
29.0		29.7	40	0	E-SE	5	30.0	21.0	-62.1
26.0		50.7	43	0	E-SE	7	28.5	21.0	-20.6
21.5		112.5	48	0	SE	8	26.5	20.0	-23.5
20.0		70.5	49	0	S-SE	[3]20	26.5	19.5	-41.4
20.0		25.4	49	0	S-SE	10	24.5	19.0	-49.2
20.0		8.8	48	0	SE	15	24.5	19.5	17.9
19.5		-1.7	48	0	SE	[4]13	24.0	20.0	53.3

[2] Gusts to 25
[3] " " 33
[4] " " 29

Also Available On Aperture Card

TI APERTURE CARD

8406040266-24

DATE: 9/13/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100	47	0.15	S-SE	[1]13	24.0	20.0	86.1
0200	50	0.01	S-SE	10	23.5	20.0	35.2
0300	47	0	SE	9	23.5	20.5	4.6
0400	47	0	S-SE	10	23.5	21.0	22.5
0500	48	0	S-SE	13	23.5	21.0	38.8
0600	50	0.83	S-SE	10	23.5	21.0	98.3
0700	55	0.78	S	28	23.5	21.0	97.7
0800	54	<0.01	S-SW	10	24.0	22.5	40.8
0900	51	0	S	[2]13	24.5	23.5	- 16.2
1000	49	0	S	10	25.5	23.5	- 34.0
1100	49	0	S	11	27.0	24.0	- 72.5
1200	46	0	S	14	29.0	23.0	- 78.1
1300	47	0	S	17	29.5	23.0	- 53.7
1400	45	0	S	15	29.0	24.0	- 45.3
1500	44	0	S	15	30.0	23.5	- 43.2
1600	45	0	S	16	30.5	23.5	- 23.2
1700	47	0	S	15	29.5	21.5	- 14.0
1800	42	0	S	8	28.5	21.0	- 6.9
1900	42	0	S	7	26.5	20.0	18.9
2000	49	0	S-SW	3	25.0	20.0	29.9
2100	50	0	SW	2000 6, 2100 19	25.0	20.0	6.9
2200	47	0	SW	3	23.0	19.0	- 5.9
2300	47	0	E-SE	3	21.5	18.5	15.8
2400	46	0	E	3	21.5	18.0	- 39.9

[1] Gusts to 21
[2] " " 20

DATE: 9/14/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)
0100	47	0	SE
0200	47	0	SE
0300	47	0	SE
0400	48	0	S-SE
0500	49	0	S-SE
0600	50	0	S-SE
0700	51	0	S-SE
0800	48	0	SE
0900	46	0	S-SE
1000	45	0	S
1100	44	0	S
1200	45	0	S
1300	43	0	S
1400	39	0	S
1500	38	0	S
1600	42	0.14	SE
1700	50	1.00	SE

[3] Gusts to
[4] @ 1650 … averaged … minute … the 6

DATE: 1/16/77

[cut off] (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
8	22.0	18.5	- 18.0							
9	22.5	19.0	- 28.4							
	23.0	23.0	- 17.3							
10	23.0	20.0	- 30.1							
9	23.0	20.0	18.2							
8	23.0	20.0	65.1							
9	23.0	20.5	136.2							
	24.0	22.0	42.4							
0	26.5	22.5	47.1							
5	28.5	22.5	22.6							
5	29.5	22.5	11.9							
3	30.0	22.5	- 31.9							
0	31.0	22.0	- 36.8							
0	32.0	22.5	- 28.8							
	32.5	22.5	- 30.5							
1	30.0	21.0	- 13.6							
0	24.0	21.0	15.9	41	0	N	3	26.5	23.0	- .9
				42	0	N-NW	3	26.0	23.0	3.[illegible]
				40	0	E	3	25.0	23.0	[illegible]
				46	0	E	1	25.0	22.5	22.5
				48	0	SE	1	24.5	22.0	.3
				48	0	SE	4	24.0	22.0	26.9
				47	0	SE	4	24.5	22.0	44.7
				46	0	SE	8	24.0	21.5	42.[illegible]

7
...ke wind speed
40 mph for about 10
... gusted to more.
0

TI APERTURE CARD

Also Available On Aperture Card

DATE: 9/17/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100	47	0	S	4	23.5	20.5	44.5
0200	45	0	S-SE	4	22.5	20.0	61.8
0300	46	0	S-SE	5	22.5	20.0	41.5
0400	45	0	S-SE	6	22.5	20.0	36.4
0500	44	0	SE	5	22.5	20.0	47.2
0600	46	0	SE	5	22.5	20.0	52.2
0700	46	0	S-SE	3	22.0	19.5	61.5
0800	47	0	S-SE	5	22.5	20.0	125.9
0900	45	0	S-SE	8	22.5	20.0	155.9
1000	44	0	S	6	23.5	20.0	124.4
1100	43	0	SW	5	25.5	20.5	86.3
1200	40	0	W-SW	5	27.0	21.0	68.4
1300	43	0	SW	8	28.5	21.0	44.1
1400	42	0	W-SW	8	30.0	21.5	39.0
1500	41	0	W	7	30.0	21.0	33.7
1600	43	0	W	8	30.0	21.0	4.0
1700	44	0	W-NW	8	30.0	21.0	- 21.5
1800	43	0	NW	6	29.0	21.0	- 29.9
1900	40	0	SE	1	27.5	21.0	6.0
2000	47	0	E-SE	1	24.5	20.5	- 7.0
2100	48	0	E	2	23.5	20.0	14.3
2200	47	0		0	22.5	19.5	26.9
2300	47	0		0	22.0	19.0	91.6
2400	46	0		0	21.5	19.0	127.3

DATE: 9/18/77

SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)
45	0	E-SE	1
46	0	SE	5
45	0	SE	6
44	0	W-SW	2
44	0	SE	2
45	0	S-SE	5
46	0	S-SE	3
47	0	S	2
45	0	SW	5
44	0	S-SE	6
43	0	S-SW	6

DATE: 9/20/77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
21.5	18.5	118.1							
22.0	19.5	61.7							
22.5	19.5	66.5							
21.5	19.0	44.9							
21.0	18.0	36.6							
22.0	19.0	53.0							
22.0	19.5	63.0							
22.5	21.0	135.5							
25.0	22.5	142.8							
27.0	22.5	112.1							
28.5	22.5	85.0							
			42	0	W-NW	5	28.0	19.0	- 43.3
			42	0	W-NW	5	28.0	19.0	- 45.8
			40	0	W-NW	4	28.0	18.5	-- 88.8
			42	0	NW	4	27.5	19.0	- 100.5
			41	0	NW	1	25.5	18.5	44.3
			46	0	E-SE	2	22.5	18.5	27.4
			46	0		0	21.0	17.5	35.8
			46	0		0	19.5	16.5	65.0
			46	0		0	19.0	16.0	78.1
			44	0	SE	1	19.0	15.5	142.2

	DATE: 9/21/77							DATE: 9/22/77			
TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AV. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AV. WIND SPEED (MPH)
0100	44	Ø	E	1	18.0	15.0	212.4	43	Ø	SE	3
0200	43	Ø	E-SE	1	17.5	14.5	201.2	43	Ø	SE	2
0300	43	Ø	SE	1	17.5	14.5	170.2	43	Ø	E	1
0400	43	Ø		Ø	17.0	14.0	150.4	42	Ø	E-SE	1
0500	44	Ø	E-NE	1	17.0	14.0	190.0	41	Ø	N	3
0600	45	Ø	E	1	17.0	14.0	270.9	41	Ø	NE	1
0700	46	Ø	E	1	17.0	14.0	232.9	43	Ø	E	2
0800	47	Ø	N-NW	1	17.5	15.5	141.2	47	Ø	NE	2
0900	41	Ø	NW	4	18.5	16.5	151.0	49	Ø	N	5
1000	45	Ø	NW	5	21.0	18.5	122.7	51	Ø	NW	5
1100	44	Ø	W-NW	5	24.5	19.5	125.0	45	Ø	NW	6
[illegible]	43	Ø	W-NW	5	27.0	17.0	65.2	46	Ø	N	9
1300	43	Ø	NW	7	27.5	17.5	66.9	50	Ø	N	8
1400	41	Ø	N-NW	7	28.5	17.0	33.4	48	Ø	N	6
1500	45	Ø	NW	7	29.0	16.5	21.3	42	Ø	N-NW	6
1600	47	Ø	NW	8	29.5	16.5	6.7	43	Ø	N	5
1700	50	Ø	N-NW	8	29.0	17.0	- 12.5	48	Ø	N	4
1800	52	Ø	N	6	27.5	17.0	22.2	37	Ø	NE	2
1900	43	Ø	NE	5	24.5	16.0	25.0	32	Ø	NE	1
2000	47	Ø	E	2	21.5	15.5	48.2	37	Ø	E-NE	3
2100	48	Ø	E-SE	3	19.5	15.0	61.0	40	Ø	E	3
2200	46	Ø	E-SE	3	18.5	15.0	108.0	42	Ø	E-SE	3
2300	45	Ø	E-NE	3	18.0	15.0	132.1	41	Ø	E-SE	4
2400	44	Ø	E	3	18.0	14.5	183.8	39	Ø	E-SE	4

DATE: 9/23/77

Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)	Sound Level (Average dBA)	Rainfall (inches)	Wind Direction (from)	Avg. Wind Speed (MPH)	Ambient Temperature (°C)	Dewpoint (°C)	Load on Line (MW)
19.0	14.5	189.6	41	0	E-SE	4	19.0	16.0	134.3
19.0	14.0	200.6	40	0	E	3	18.5	15.5	103.2
17.0	14.0	178.9	42	0	E-SE	5	19.0	15.5	90.3
16.5	14.0	177.3	42	0	NE	3	18.5	15.0	60.3
16.0	13.5	210.8	40	0	E	2	18.0	15.0	102.5
16.0	13.5	286.2	41	0	E	2	17.5	15.0	210.2
16.0	13.5	263.2	43	0	E-NE	2	17.5	15.0	244.4
17.0	15.0	208.1	43	0	N-NE	3	19.5	17.0	191.9
19.5	16.5	161.1	43	0	SE	9	23.5	19.0	181.9
22.0	17.0	217.3	48	0	SE	13	25.5	19.5	155.8
25.0	17.5	190.4	47	0	SE	10	27.0	20.5	137.8
26.5	16.0	188.3	44	0	SE	8	29.5	20.5	115.1
27.5	16.0	206.6	43	0	S-SE	8	30.0	20.0	97.4
29.0	16.5	170.9	40	0	S	9	31.0	20.5	52.8
29.5	16.5	140.1	38	0	S	7	31.5	20.5	24.9
30.0	16.5	153.5	32	0	S	7	32.0	20.0	31.2
30.0	16.5	123.0	<30	0	S	6	31.0	20.5	27.4
29.0	17.5	116.7	<30	0	S-SE	3	29.0	21.5	26.5
25.0	18.0	115.6	<30	0	SE	3	27.0	21.5	44.8
21.5	17.5	126.6	31	0	SE	4	25.0	21.5	40.1
20.0	16.5	111.6	33	0	S-SE	5	25.5	21.0	34.0
21.0	16.5	163.9	36	0	SE	5	25.0	20.5	39.1
20.0	16.5	132.1	37	0	SE	6	24.5	20.5	75.2
19.0	16.0	121.2	40	0	SE	6	24.5	20.0	96.8

DATE: 9/24/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100	42	0	SE	6	24.0	19.5	108.3
0200	43	0	SE	6	23.5	19.0	75.5
0300	46	0	SE	6	23.0	19.0	18.4
0400	47	0	SE	8	23.0	18.5	1.2
0500	49	0	SE	7	22.5	18.0	99.3
0600	48	0	SE	6	22.5	18.0	158.1
0700	48	0	SE	8	22.0	18.0	208.3
0800	48	0	S-SE	9	22.5	18.0	257.1
0900	47	0	SE	7	23.5	18.5	256.6
1000	47	0	S-SE	6	25.0	19.0	211.1
1100	45	0	S	7	26.0	20.0	160.7
1200	45	0	S	9	28.0	21.0	133.7
1300	43	0	S	7	29.0	21.0	75.6
1400	42	0	SW	6	29.5	21.0	84.3
1500	40	0	SW	5	29.5	20.5	101.4
1600	42	0	N	6	29.0	20.5	105.1
1700	42	0	NW	5	28.0	20.5	108.3
1800	44	0	NW	3	27.5	21.5	82.8
1900	45	0	SW	3	26.0	21.0	106.1
2000	51	0	S-SE	6	25.5	21.0	111.1
2100	52	0	S-SE	10	25.0	21.5	90.0
2200	51	0	S-SE	8	25.0	21.0	104.9
2300	50	0	S-SE	4	24.5	20.5	143.4
2400	48	0	S-SE	5	23.5	20.0	145.3

DATE: 9/25/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
0100	49	0	SE	7
0200	49	0	SE	8
0300	49	0	SE	9
0400	50	0	SE	7
0500	49	0	SE	9
0600	49	0	SE	9
0700	50	0	S-SE	9
0800	48	0	S-SE	10
0900	45	0	S	12[1]
1000	44	0	S	11
1100	43	0	S-SW	7
1200	43	0	S-SW	7
1300	41	0	SW	8
1400	39	0	SW	6
1500	40	0	S-SW	4
1600	44	0	S	6
1700	48	0	SE	5
1800	55	1.00	NE	[2] 20
1900	65	0.50	N	[2] 20
2000	55	0.28	NE	10
2100	53	0.01	S-SE	16
2200	48	0	SE	17
2300	47	0	SE	5
2400	47	0	SE	6

[1] GUSTS TO 20
[2] " " >40

DATE: 9/26/77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
23.5	20.0	136.5	46	0	SE	3	21.0	19.0	- 98.7
23.5	20.0	116.5	45	0	SE	9	21.0	19.0	57.8
23.5	20.0	144.1	45	0	SE	8	21.0	19.0	48.8
23.5	20.0	140.4	45	0	S-SE	10	21.0	19.5	54.0
23.5	20.5	121.9	44	0	S-SE	10	21.0	19.0	65.9
23.5	20.5	132.7	43	0	S-SE	10	21.5	19.5	172.1
23.5	20.5	157.1	43	0	S-SE	6	21.5	20.0	243.4
24.0	21.0	216.0	42	0	S	8	22.5	21.5	193.4
26.0	22.5	199.8	40	0	S	9	24.5	23.0	72.7
26.5	23.0	153.8	41	0	SW	8	25.0	24.0	24.5
28.5	24.5	133.7	39	0	W-SW	7	25.0	24.0	- 24.9
30.0	24.0	126.4	38	0	W-SW	7	27.5	24.5	- 29.5
30.5	24.5	66.2	38	0	W	6	28.5	24.5	- 14.0
30.5	24.0	46.8	39	0	N-NW	7	29.0	23.0	- 66.2
30.0	24.0	45.3	39	0	NE	3	30.5	22.5	- 62.7
29.5	24.0	84.2	38	0	SE	4	31.0	22.5	- 90.0
28.0	24.0	70.9	38	0	SE	6	31.0	23.0	- 135.1
22.5	20.5	73.1	38	0	S-SE	2	30.5	24.0	- 130.8
22.0	20.0	82.2	42	0	S-SW	2	28.0	23.5	- 94.9
21.0	19.0	97.9	49	0	SE	1	24.5	23.0	- 89.5
21.0	19.5	85.5	49	0	S	3	24.0	23.0	- 84.0
21.0	19.5	137.8	50	0	S	4	25.0	23.0	- 99.7
21.0	19.5	169.0	48	0	S	2	24.0	22.5	- 50.5
21.0	19.0	141.5	46	0	S-SE	3	23.0	22.5	- 1.1

DATE: 9/27/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
0100	45	0	SE	1	23.0	22.0	41.7
0200	44	0	SE	4	22.0	21.5	80.5
0300	45	0	SE	4	22.0	22.0	97.5
0400	48	0	SE	6	22.5	22.5	78.4
0500	43	0	S-SE	6	22.5	22.0	100.4
0600	43	0	S	6	22.5	22.0	119.9
0700	42	0	S	5	22.5	22.0	80.4
0800							
0900							
1000							
[illegible]							
1200							
1300							
1400							
1500							
1600							
1700							
1800							
1900							
2000							
2100							
2200							
2300							
2400							

DATE: 9/30/77

TIME	SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)
1600	42	0	E-SE	9
1700	41	0	E-SE	8
1800	41	0	SE	6
1900	44	0	SE	7
2000	45	0	SE	9
2100	44	0	SE	10
2200	45	0	SE	12
2300	44	0	SE	13
2400	43	0	SE	13

DATE: 10/01/77

AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
28.0	23.0	- 42.7
28.0	23.5	- 62.4
27.0	23.0	- 51.4
25.5	22.5	4.7
25.0	22.5	11.8
25.0	22.5	16.5
24.5	22.0	32.7
24.0	22.0	48.9
24.0	22.0	43.6

SOUND LEVEL (AVERAGE dBA)	RAINFALL (INCHES)	WIND DIRECTION (FROM)	AVG. WIND SPEED (MPH)	AMBIENT TEMPERATURE (°C)	DEWPOINT (°C)	LOAD ON LINE (MW)
43	0	S-SE	11	24.0	22.5	-25.5
43	0	S-SE	[1]13	24.5	23.0	42.9
44	0	S	[1]15	25.5	23.0	60.9
42	0	S	[2]12	26.0	23.5	65.2
45	0	S	[2]11	26.0	24.0	69.1
43	0	S	[2]11	25.5	24.5	92.0
43	0	S	[2]11	26.0	24.0	112.5
43	0	S	11	26.0	24.0	111.2
40	0	S	10	26.5	24.0	143.7
43	0	S-SW	12	27.5	24.5	51.0
46	0	SW	15	29.5	24.5	- 16.9

Also Available On Aperture Card

[1] GUSTS TO 29
[2] " " 22

TI APERTURE CARD

8406040266-29