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The Effects of Local Meteorological Factors upon Aircraft Noise Measurements

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THE EFFECTS OF LOCAL METEOROLOGICAL FACTORS UPON AIRCRAFT NOISE MEASUREMENTS

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16. Abstract

Aircraft noise measurements from the Boeing 737, made at Orange County Airport, Santa Ana, California, during operational conditions, are statistically correlated with the local meteorological factors including wind force and direction, temperature, humidity barometric pressure, ceiling and visibility. The correlation was carried out using regression techniques and indicated that there is a significant inverse correlation between temperature and noise level. Wind speed appeared to be of significance in one calculation that included wind speeds up to 25 knots, but was not significant when the range of wind speeds was 15 knots and below.

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PREFACE

Ultrasystems, Incorporated wishes to thank Mr. J. K. Powers and Mr. T. H. Higgins, Technical Representatives of the Noise Abatement Division of the Federal Aviation Administration, for initiating this program and for providing many helpful suggestions during the course of the work.

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CONTENTS

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INTRODUCTION

The effects of meteorological conditions upon sound propagation in air are to a large extent known; however, the importance of the various meteorological conditions upon measured community noise levels during actual aircraft operations has not previously been determined. The objective of this project was to separate out and examine the effects of local meteorological conditions upon measured community aircraft noise exposure.

The study utilizes data measured at Orange County Airport in Santa Ana, California. For over a year, the Orange County Airport noise abatement office has been monitoring and recording noise levels in the surrounding community due to aircraft operations at the airport. Several thousand sound level measurements have been recorded which include both takeoff and landing sound levels produced by the Boeing 737, the Douglas DC-9 and most of the more popular business jet aircraft. Associated with the direct noise measurements, related data have been collected on weather conditions, noise abatement procedures, community noise exposure levels and noise complaint histories. A part of the very large data bank containing the information was used for this study. A principal advantage of this data is that it provides information taken in the community surrounding the airport over a long period of time, under varying meteorological and operational conditions.

BACKGROUND

It is well known that the propagation of sound in the atmosphere is dependent upon local meteorological parameters. The FAA noise standards for aircraft type certification,[1] for example, specify the corrections for non-standard atmospheric conditions that must be made to the EPNL calculated from measured noise data. These corrections are based upon data presented in SAE ARP 866.[2] The noise standards also place limitations upon the range of meteorological conditions under which noise certification tests can be carried out. Known atmospheric absorption data can therefore be utilized to correct measured noise levels for meteorological conditions so that the measured noise levels can be referenced to standard atmospheric conditions. Recent measurements of the flyover noise from a T-33A aircraft were used to experimentally determine atmospheric absorption.[3] The aircraft was flown at nominal 100 percent engine power on straight and level flybys. Measured noise and meteorological data were used to determine experimental absorption coefficients. The results indicate that for elevation angles greater than 15 degrees calculations from ARP 866 generally underestimate the air-to-ground absorption coefficients, and for elevation angles less than 15 degrees the ex- experimental absorption coefficients agree with and, in some cases, fall below the ARP 866 predictions. Except for some scatter at low frequencies and errors at high frequencies due to interference from background noise, the measured absorption coefficients show the same trends as the predicted values. Thus, provided the propagation path is known, atmospheric attenuation of aircraft noise can be determined with reasonable accuracy.

The effect of meteorological conditions upon community noise from aircraft measured over a period of time, however, involves factors other than atmospheric absorption. In addition to its effects upon atmospheric attenuation, for example, temperature also strongly affects aircraft performance and thereby indirectly affects measured community noise. The work carried out in this program was aimed at assessing the effects of temperature, humidity, wind force and direction, visibility, and ceiling upon measured community noise by correlating these factors with measured noise data.

The Orange County Airport noise monitoring system provides a continuous area-wide monitoring of the airport's noise environment. The monitoring system presently consists of five microphone sensors arrayed in both the landing and departure zones of the airport as shown in Figure 1. Under most conditions, runway 19R is normally used for both landing and departure. Three microphone sensors are located in the departure zone; one is along the runway centerline about 10,000 ft from the brake release point, and the other two are about 3,000 ft on each side of the departure flight path and about 16,000 ft from the brake release point. Two additional microphones are located along the runway centerline in the approach zone at about 29,000 ft and 6,000 ft, respectively, from the point of touchdown. The output of each microphone is in A-weighted decibles with a dynamic range of 60 to 120 dB(A). The sensors conform to applicable sections of IEC 179, ANSI S1.4-1971 and the Noise Standard for California Airports. Output accuracy is ±1.0 dB and each station has logged over 3,000 hours during the past year and has remained within calibration while exposed to the outdoor environment. Each sensor transmits a frequency modulated signal over private telephone lines to a central processing computer located at the airport terminal.

A teletype and display output unit, connected to the central processor, print the formulated data and serve as the input unit for the operator-selected operational instructions. The system can be set to operate and provide information according to a variety of formats by selecting threshold levels at each station, resolution limits, maximum and minimum event times, and minimum excursion values for each station. Using the various parameters available in the system, almost all nonjet aircraft events can be rejected or any class of events capable of description by the applicable parameters can be selected. The system normally prints out single event noise exposure level (SENEL) which is the A-weighted noise exposure

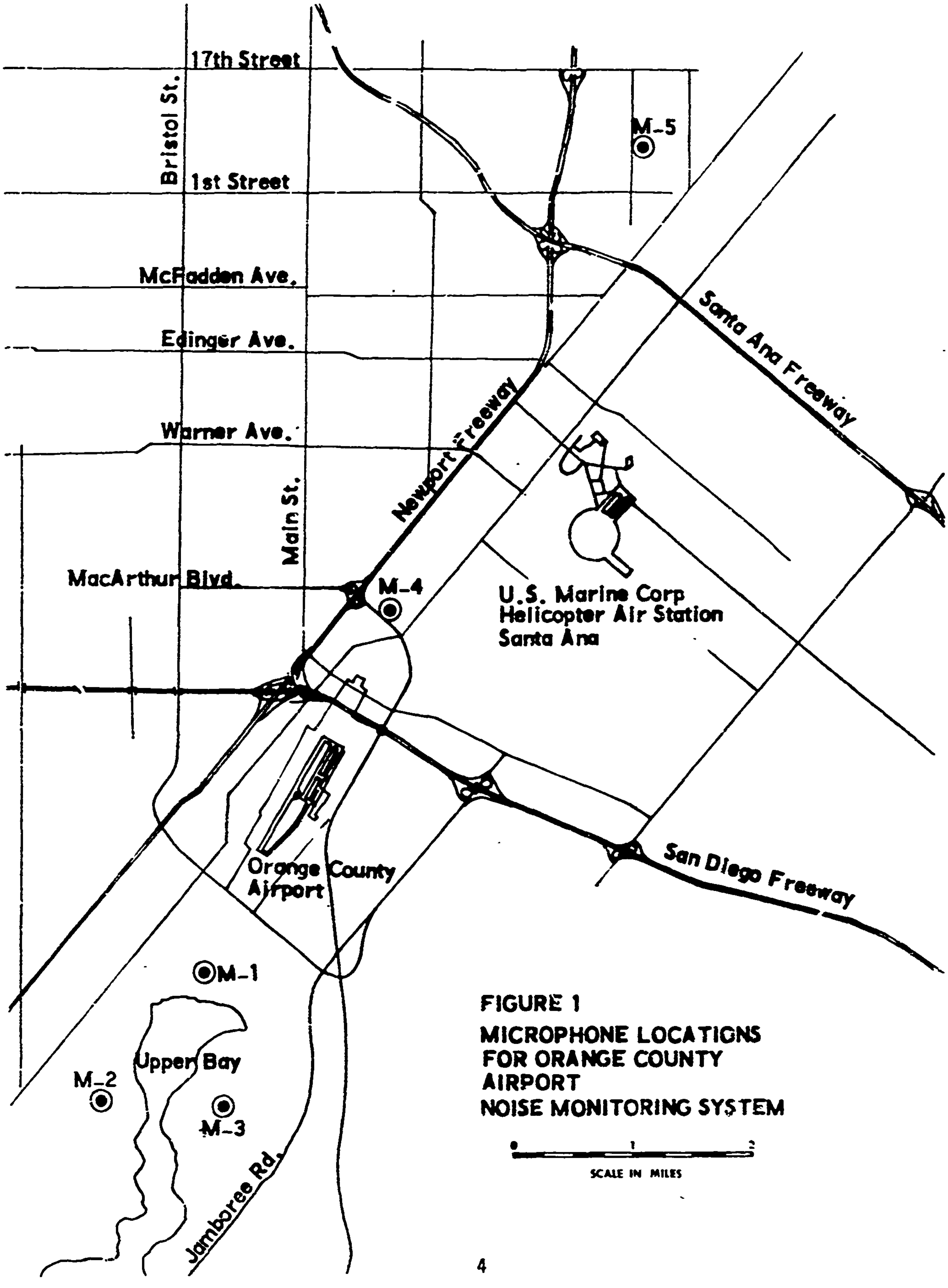

FIGURE 1
MICROPHONE LOCATIONS
FOR ORANGE COUNTY
AIRPORT
NOISE MONITORING SYSTEM

level for a single event, hourly noise level (HNL) which is the average (on an energy basis) A-weighted noise level during a particular hour, and community noise equivalent level (CNEL) which is an average A-weighted noise level during a 24-hour day, adjusted to an equivalent level to account for the lower noise tolerance of people in the evening and night-time periods relative to the daytime periods. In addition, a true histogram of individual or multiple station events may be printed out. The detailed methods for calculating the SENEL, HNL and CNEL are given in the "Adopted Noise Regulations for California Airports."[4]

The noise measurements used in the present calculations are the SENEL measurements, which are closely related to the effective perceived noise level (EPNL) for a single noise event. This study is limited to flyover noise from the Boeing 737 aircraft (operated by Air California out of Orange County Airport) to avoid variations that could be introduced into the data by the use of a mix of aircraft types. Only takeoff noise data are used for the calculations. Each calculation was made for SENEL values which were measured at a given microphone for the Boeing 737 during takeoff. In addition to the effects of meteorological conditions, other variables that influence the measured data are the aircraft gross weight, the particular aircraft producing the noise event, the pilot or pilot technique, and other more secondary effects such as maneuvers to avoid other traffic, VFR versus instrument departures, etc. The analysis carried out here only accounts for the effects of the meteorological parameters.

STATISTICAL ANALYSIS OF DATA

For each of the nine matrices of collected data tabulated in Appendix A, a complete multiple regression analysis was conducted. The results of these individual analysis runs are presented as Appendix B.

The dependent parameter, Y, used throughout was the observed noise level (SENEL) at microphone station #1 except for Runs 7, 8, and 9 which used data from microphones #2, #3, and #4, respectively.

The following is a list of the independent variables, X_i, which were studied in at least one analysis run.

1. Wind Speed, overall (knots)
2. Wind Direction (degrees from flight path)
3. Flight path down-wind vector (knots)
4. Flight path cross-wind vector (knots)
5. Visibility (miles)
6. Ceiling, reciprocal $(\text{feet})^{-1}$
7. Temperature (°R)
8. Relative humidity (percent).

The major purpose of the experiment was to discover which factors from the system of independent external meteorological conditions of interest could be statistically related to the observed aircraft noise level as measured at a fixed microphone station. The statistical technique used to perform the evaluation was "multiple linear regression."[5]

The input for the analysis is a data matrix of the following form:

Y	X_1	X_2	. . . .	X_k
Y_1	X_{11}	X_{12}	. . . .	X_{1k}
Y_2	X_{21}	X_{22}	. . . .	X_{2k}
.	.	.		.
.	.	.		.
.	.	.		.
.	.	.		.
Y_N	X_{N1}	X_{N2}		X_{Nk}

These data arrays for each of the nine analysis runs made are given in Appendix A, and Appendix B presents the corresponding analysis results for each of the nine runs made.

The analysis of variance is presented at the top of each page in Appendix B. Basically, this analysis provides a measure of the relative significance of each independent factor as it relates to the dependent variable, which in this case is the measured noise level, Y. The quantity "F" in the next to last column is the statistic that provides the basis for the significance test of each regression coefficient. The larger the value of "F" the more significant the independent variable is. The final column is a code of the significance levels having the following meanings:

- - : the corresponding factor is <u>not</u> significantly correlated with Y
- + : the corresponding factor <u>is</u> significantly correlated with Y at the 95 percent confidence level
- ++ : the corresponding factor <u>is</u> significantly correlated with Y at the 99 percent confidence level
- +++ : the corresponding factor is significantly correlated with Y at the 99.9 percent confidence level.

The multiple correlation coefficient, R, provides an estimate of the overall level of correlation for the particular analysis. A value near zero indicates a relatively low correlation, while a value of R near + 1 (or -1) indicates high correlation and a near perfect predictability of Y from the given system of independent variables.

The value of R^2 represents the overall fraction of the original variation in Y which is accounted for by the regression. The remaining variance, the prediction error, is then due to a combination of experimental error (measurement errors, etc.) and the effects of additional significant factors which are not a part of the current system of independent variables.

The least squares prediction equation resulting from the regression analysis is of the form:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_k X_k$$

where the b_i are the estimated regression coefficients. The quantity s_E is the estimated standard deviation of error of the fitted equation. The results of the nine analysis runs are discussed below.

Run No. 1

Multiple linear regression Run No. 1 was conducted for the SENEL measured at microphone #1, as a function of temperature, humidity, wind speed, wind direction, and visibility. Temperature and humidity were input as exponential factors, whereas wind speed, wind direction, and visibility were input as linear factors. Wind speed, wind direction and visibility data were obtained from Orange County Airport weather reports. Temperature and humidity were obtained from Orange County Agricultural Department weather reports.* For conditions of zero wind speed, random numbers from 0-360 were used for wind direction.

*The Orange County Agricultural Department maintained a weather station near the control tower at the Orange County Airport until 1 January 1972.

The major statistical result for this run, as seen in Appendix B, was that temperature had a very large inverse effect on the measured noise level. The higher the temperature, the smaller the noise level.

The only other effect showing up significantly on this run was wind direction for which a marginal significance at the 95 percent confidence level was indicated.

Run No. 2

The data used for the second correlation was the same as for the first. However, only the effects of temperature and wind direction were considered. As before, temperature was input as an exponential factor, whereas wind direction was input as a linear factor. Conditions of zero wind speed were discarded in order to test the validity of using random numbers for wind direction under such conditions.

The results of this run were essentially the same as for the first run.

Run No. 3

For the third study, the same set of data was used as for Run No. 1. Temperature was input as a linear factor. All other conditions were the same as for the second run.

The results for this run indicated that temperature alone was significant. The overall result as measured by R was somewhat less than Run No. 2; thus, it was concluded that for the future analysis the exponential transformation of temperature would be retained.

Run No. 4

Analysis No. 4 was run for the SENEL measurement by microphone #1 as a function of temperature, ceiling, and wind down the runway. Temperature was input as an exponential factor, ceiling was input as an inverse factor, and wind down the runway was input as a linear factor. The wind down the runway was computed as the vector component in the d rection of the wind down the runway. Temperature data was obtained f om Orange County Agricultural Department weather reports. Ceiling, wind speed, and wind direction data were obtained from Orange County Airport weather reports.

None of the factors indicated a significant relationship with noise level on this run. The range of temperatures included for this run was much narrower than in prior runs, and, thus, perhaps was not wide enough for the effect to show up in the calculations.

Run No. 5

Analysis No. 5 was run for the SENEL measured at microphone #1 as a function of temperature, crosswind, and wind down the runway. Temperature was input as an exponential factor, whereas crosswind and wind down the runway were treated as linear factors. Wind down the runway was computed as in Correlation No. 4. Crosswind was computed as the vector component of the wind perpendicular to the runway. The data were obtained from the same sources as for Run No. 4.

Only temperature indicated a significant inverse relationship with noise level, as in prior runs.

Run No. 6

For Study No. 6, a completely new data set was obtained. SENEL of microphone #1 was correlated versus temperature, humidity, wind speed, and wind direction. Temperature and humidity were input as exponential factors, whereas wind speed and wind direction were input as linear factors. Random numbers were used for wind direction data in the cases of zero wind speed. Humidity data were obtained from United States Marine Corps

Helicopter Air Station, Santa Ana, California, (see Figure 1) weather reports. Temperature, wind speed, and wind direction data were obtained from Orange County Airport weather reports.

The results of this run indicated that, again, the inverse effect of temperature was very significant. None of the other factors considered were found to be significant.

Run No. 7

Run No. 7 was conducted for the SENEL of microphone #2 as a function of temperature, humidity, wind speed, wind direction, and visibility. All conditions were the same as for Run No. 1 except the microphone.

The results were essentially the same as found for microphone #1 with the effect of temperature being the only significant factor.

Run No. 8

Study No. 8 was run for the SENEL of microphone #3 as a function of temperature, humidity, wind speed, wind direction, and visibility. As for Run No. 7, conditions were the same as for Run No. 1 except the microphone. Fewer data sets were used since microphone #3 did not function properly during some of the flights.

The results were essentially the same as the run for the other two microphones. Thus, the results do not seem to substantially differ as a function of microphone placement.

Run No. 9

A completely new data set was obtained for Analysis No. 9. For all previous correlations, data were used for flights departing to the south. For this run, data were used for flights departing to the north. The correlation was run for microphone #4 as a function of temperature, humidity, wind speed, and wind direction. Temperature and humidity were input as exponential factors, whereas wind speed and wind direction were input as linear variables. Random numbers were input as data for wind direction for the conditions of zero wind speed. Humidity data were obtained from United States Marine Corps Helicopter Air Station, Santa Ana, California, weather reports. Temperature, wind speed, and wind direction were obtained from Orange County Airport weather reports.

The results of this analysis indicated the presence of wind speed as a significant inverse effect for the first time. It may have been a real effect previously; however, the range of wind speeds present was perhaps not sufficiently large for the true effect to be seen. The wind speed range for this run was 0-25 knots. The effect of temperature did not, however, show up on this run, probably because range of temperature was somewhat narrow on this particular data set.

SUMMARY AND CONCLUSIONS

The inverse effect of temperature was the only dominant effect that was repeatable throughout the nine runs. There were only two cases which did not indicate the temperature variable as significant, and in both of these cases the range of temperature variation was considerably below that of the other runs.

The effect of wind direction, although showing up significantly on related Runs 1 and 2, may very well not be a "real" effect. It did not have a large effect, even on these runs, and it did fail to show up significantly on any of the other runs. It should be mentioned that an "unreal" effect showing up with significance code + will happen about one time in twenty and, clearly, this would not be too unlikely here since about 30 tests of significance were made in the overall analysis.

The effect of wind speed, likewise, only showed up one time; however, this more likely represents a real effect since the run on which it did show up was Run No. 9, where the data set possessed the greatest range for this factor (i.e., wind speeds up to 25 knots were observed). More data sets with large wind speed ranges should, however, be analyzed before this factor is accepted as being "real." Run No. 9 was made using recently acquired data taken during a so-called "Santa Ana" weather condition. This local weather condition is characterized by high winds from the north and very low humidity. A Santa Ana weather condition occurred during the later stages of the program and, because Orange County noise abatement personnel were noticing generally lower noise levels,[6] a regression calculation was made using new data taken during this condition.

None of the other factors appear to be significantly related to noise level; however, some of these factors should also be studied over wider ranges to be more certain that they are not significant.

It should be noted that, although humidity is an important variable affecting the attenuation of sound in the atmosphere, humidity was not a statistically significant factor in any of the runs made here. This was the case even though humidity varied over a fairly wide range in all the runs in which it was included. Based upon the calculations made here humidity, therefore, is apparently not an important parameter in the measured community noise from aircraft. This is a tentative conclusion based upon a limited number of calculations, however, and would require further calculations based upon a wider range of data to fully substantiate.

Some error was introduced by interpolation of the meterological factors since data in all cases were not available at the time of the noise event. Continuous monitoring of these parameters would reduce this error.

This work indicates that temperature and possibly wind speed are the most important factors affecting measured aircraft noise levels under operating conditions. The local meteorological factors generally account for about one-fourth to one-third of the variations in measured noise levels. This indicates that an improvement of predicated airport noise levels may possibly be achieved by proper consideration of these parameters. Of more importance is the possibility that the consideration of meteorological parameters may significantly assist in airport noise abatement planning and evaluation. This work serves to indicate the relative importance of meteorological parameters in measured community aircraft noise. Further work using a wider data base at several locations would be required to substantiate these results and lead to information that would be of significant usefulness in noise abatement and prediction activities.

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1. "Federal Aviation Administration, Part 36 - Noise Standards Aircraft Type Certification," November 1969.

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3. Tanner, C. S., "Experimental Atmospheric Absorption Coefficients," Federal Aviation Administration Report No. FAA-RD-71-99, November 1971.

4. State of California Administrative Code, Title 4 Subchapter 6, entitled "Noise Standards" (Register 70, No. 48-11-28-70) pp. 391-420.

5. Dixon, W. J. and Massey, F. J. Introduction to Statistical Methods, 3rd Edition McGraw-Hill, 1969, p. 212.

6. N. G. Ewers, Noise Abatement Specialist, Orange County Airport (private communication).

APPENDIX A – TABULATED DATA

DATA SET NO. 1

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)	Visibility (Miles)
10/10/71	7:30	112.0	55	92	4	125	0.3
	11:05	103.0	90	37	0	40*	2.0
	11:28	100.5	92	35	5	210	2.0
	12:35	99.0	94	31	11	240	2.5
	13:04	99.5	94	30	13	270	3.0
	13:58	97.0	89	37	13	260	3.0
10/12/71	7:50	106.0	64	85	0	220*	0.1
	7:52	105.0	64	85	0	100*	0.1
	8:40	103.5	70	78	0	150*	2.0
	8:56	108.5	71	77	0	10*	3.0
	9:55	107.5	76	67	5	250	4.0
	10:33	103.5	75	69	8	235	4.0
	10:50	102.5	74	70	10	225	4.0
	11:00	101.5	74	71	11	220	4.0
	12:37	104.0	73	69	9	240	5.0
	13:03	105.5	73	69	13	240	5.0
	13:39	99.5	73	70	12	240	6.5
10/30/71	10:01	105.5	62	70	7	180	10.0
	10:39	99.5	62	71	9	220	10.0
	10:59	101.5	62	71	10	240	10.0
	11:50	103.5	62	71	10	240	14.0
	12:40	101.5	62	72	11	225	15.0
	13:04	102.5	62	72	12	220	15.0

*Data obtained from Random Number Catalog.

DATA SET NO. 1 (CON'T)

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)	Visibility (Miles)
12/3/71	7:18	94.5	47	86	0	360*	40.0
	7:40	96.0	48	75	0	40*	40.0
	8:02	106.0	49	66	0	190*	40.0
	8:34	108.5	52	63	0	230*	40.0
	10:04	106.5	55	53	0	110*	20.0
	10:11	101.5	55	53	0	250*	20.0
	10:35	104.0	56	53	0	320*	20.0
	11:49	104.0	55	57	0	60*	20.0
	11:57	98.5	55	58	0	350*	20.0
	12:35	106.0	54	60	4	240	20.0
12/26/71	9:05	104.5	54	73	5	160	20.0
	10:03	107.5	55	72	10	240	20.0
	10:53	104.5	55	72	12	240	20.0
	11:05	108.0	55	72	12	240	20.0
	12:16	107.0	55	70	15	240	20.0
	12:18	105.5	55	69	15	240	20.0
	13:03	108.0	55	65	15	240	20.0
	13:35	107.0	55	64	14	240	20.0
	13:50	108.0	55	63	13	240	20.0
	13:53	103.0	55	63	13	240	20.0
12/29/71	9:20	106.0	45	91	3	90	40.0
	9:39	101.0	48	88	3	100	40.0
	9:54	107.5	49	86	3	105	40.0
	10:15	103.5	51	82	3	140	40.0
	11:58	104.5	54	68	4	250	20.0
	14:43	104.0	54	68	12	230	16.0

*See footnote, page 17

Temperature and Humidity data obtained from Orange County Agricultural Department weather reports. Wind Speed, Wind Direction, and Visibility data obtained from Orange County Airport weather reports.

DATA SET NOS. 2 AND 3

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Wind Direction (°From True North)
10/10/71	7:30	112.0	55	125
	11:28	100.5	92	210
	12:35	99.0	94	240
	13:04	99.5	94	270
	13:58	97.0	89	260
10/12/71	9:55	107.5	76	250
	10:33	103.5	75	235
	10:50	102.5	74	225
	11:00	101.5	74	220
	12:37	104.0	73	240
	13:03	105.5	73	240
	13:39	99.5	73	240
11/30/71	10:01	105.5	62	180
	10:39	99.5	62	220
	10:59	101.5	62	240
	11:50	103.5	62	240
	12:40	101.5	62	225
	13:04	102.5	62	220
12/3/71	12:35	106.0	54	240
12/26/71	9:05	104.5	54	160
	10:03	107.5	55	240
	10:53	104.5	55	240
	11:05	108.0	55	240
	12:16	107.0	55	240
	12:18	105.5	55	240
	13:03	108.0	55	240
	13:35	107.0	55	240

DATA SET NOS. 2 AND 3 (CON'T)

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Wind Direction (°From True North)
12/26/71 (Con't)	13:50	108.0	55	240
	13:53	103.0	55	240
12/29/71	9:20	106.0	45	90
	9:39	101.0	48	100
	9:54	107.5	49	105
	10:15	103.5	51	140
	11:58	104.5	54	250
	14:43	104.0	54	230

Temperature data obtained from Orange County Agricultural Department weather reports. Wind Direction data obtained from Orange County Airport weather reports.

DATA SET NO. 4

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Wind Speed (Knots)	Wind Direction (°From True North)	Ceiling (Ft)
10/12/71	7:50	106.0	64	0	-	25,000
	7:52	105.0	64	0	-	25,000
	8:40	103.5	70	0	-	25,000
	8:56	108.5	71	0	-	25,000
	9:55	107.5	76	5	250	25,000
	10:33	103.5	75	8	235	25,000
	10:50	102.5	74	10	225	25,000
	11:00	101.5	74	11	220	25,000
	12:37	104.0	73	9	240	none
	13:03	105.5	73	13	240	none
	13:39	99.5	73	12	240	none
11/30/71	10:01	105.5	62	7	180	3,000
	10:39	99.5	62	9	220	3,000
	10:59	101.5	62	10	240	3,000
	11:50	103.5	62	10	240	3,000
	12:40	101.5	62	11	225	3,000
	13:04	102.5	62	12	220	3,000
12/3/71	7:18	94.5	47	0	-	none
	7:40	96.0	48	0	-	none
	8:02	106.0	49	0	-	none
	8:34	108.5	52	0	-	5,000
	10:04	106.5	55	0	-	15,000
	10:11	101.5	55	0	-	15,000
	10:35	104.0	56	0	-	15,000
	11:49	104.0	55	0	-	15,000
	11:57	98.5	55	0	-	15,000
	12:35	106.0	54	4	240	15,000

DATA SET NO. 4 (CON'T)

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Wind Speed (Knots)	Wind Direction (°From True North)	Ceiling (Ft)
12/26/71						
12/26/71	9:05	104.5	54	5	160	2,200
	10:03	10[illegible].5	55	10	240	2,200
	10:53	10[illegible].5	55	12	240	2,200
	11:05	108.0	55	12	240	2,200
	12:16	107.0	55	15	240	2,200
	12:18	105.5	55	15	240	2,200
	13:03	108.0	55	15	240	2,200
	13:35	107.0	55	14	240	2,200
	13:50	108.0	55	13	240	2,200
	13:53	103.0	55	13	240	2,200
12/29/71	9:20	106.0	45	3	90	none
	9:39	101.0	48	3	100	none
	9:54	107.5	49	3	105	none
	10:15	103.5	51	3	140	900
	11:58	104.5	54	4	250	3,500
	14:43	104.0	54	12	230	2,500

Temperature data obtained from Orange County Agricultural Department weather reports. Wind Speed, Wind Direction, and Ceiling data obtained from Orange County Airport weather reports.

DATA SET NO. 5

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Wind Speed (Knots)	Wind Direction (°From True North)
10/10/71	7:30	112.0	55	4	125
	11:05	103.0	90	0	-
	11:28	100.5	92	5	210
	12:35	99.0	94	11	240
	13:04	99.5	94	13	270
	13:58	97.0	89	13	260
10/12/71	7:50	106.0	64	0	-
	7:52	105.0	64	0	-
	8:40	103.5	70	0	-
	8:56	108.5	71	0	-
	9:55	107.5	76	5	250
	10:33	103.5	75	8	235
	10:50	102.5	74	10	225
	11:00	101.5	74	11	220
	12:37	104.0	73	9	240
	13:03	105.5	73	13	240
	13:39	99.5	73	12	240
11/30/71	10:01	105.5	62	7	180
	10:39	99.5	62	9	220
	10:59	101.5	62	10	240
	11:50	103.5	62	10	240
	12:40	101.5	62	11	225
	13:04	102.5	62	12	220
12/3/71	7:18	94.5	47	0	-
	7:40	96.0	48	0	-
	8:02	106.0	49	0	-
	8:34	108.5	52	0	-
	10:04	106.5	55	0	-

DATA SET NO. 5 (CON'T)

Date	Time	SENEL M-1 (dB)	Temperature (	Wind Speed (Knots)	Wind Direction) (°From True North)
12/3/71 (Con't)	10:11	101.5	55	0	-
	10:35	104.0	56	0	-
	11;49	104.0	55	0	-
	11:57	98.5	55	0	-
	12:35	106.0	54	4	240
12/26/71	9:05	104.5	5[illegible]	5	160
	10:03	107.5	55	10	240
	10:53	104.5	55	12	240
	11:05	108.0	55	12	240
	12:16	107.0	55	15	240
	12:18	105.5	55	15	240
	13:03	108.0	55	15	240
	13:35	107.0	55	14	240
	13:50	108.0	55	13	240
	13:53	103.0	55	13	240
12/29/71	9:20	106.0	45	3	90
	9:39	101.0	48	3	100
	9:54	107.5	49	3	105
	10:15	103.5	51	3	140
	11:58	104.5	54	4	250
	14:43	104.0	54	12	230

Temperature data obtained from Orange County Agricultural Department weather reports. Wind Speed and Direction obtained from Orange County Airport weather reports.

DATA SET NO. 5

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)
9/4/72	8:22	105.0	71	81	2	290
	9:38	92.5	74	71	7	300
	10:07	105.5	76	64	8	300
	10:37	107.5	78	58	6	300
	11:14	100.0	80	54	6	300
	13:13	98.5	87	52	9	220
	13:28	103.0	87	51	11	230
	13:49	103.5	88	50	14	250
	13:50	99.5	88	50	14	250
9/5/72	10:05	105.0	78	[illegible]	5	240
9/15/72	14:04	94.0	75	[illegible]	2	230
	14:08	106.0	75	[illegible]	2	230
9/22/72	12:37	102.0	76	75	10	210
	13:06	104.5	77	78	10	190
9/23/72	11:50	100.5	70	62	11	220
	11:57	100.5	70	62	12	220
	12:06	102.5	70	62	12	220
	12:42	99.5	69	59	14	230
	13:19	99.0	69	68	15	230
	14:28	103.0	69	60	15	230
	14:33	97.0	69	60	15	230
9/25/72	11:09	99.0	71	57	7	210
	11:43	98.5	69	54	5	220
	11:49	101.5	69	54	5	220

DATA SET NO. 6 (CON'T)

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)
9/26/72	10:04	104.5	70	60	4	180
	11:50	98.0	70	73	13	240
	11:52	96.5	70	74	14	240
	11:53	104.5	70	74	14	240
	12:33	103.0	70	77	9	250
	13:34	107.0	71	72	9	250
	14:39	102.5	72	65	9	250
9/28/72	8:41	107.0	63	79	4	40
	8:53	100.0	64	78	4	40
	9:55	10.45	68	70	5	230
9/30/72	8:29	106.0	61	86	0	150*
	8:33	102.5	61	84	0	210*
	9:09	106.0	64	69	1	270
	9:12	104.0	72	68	1	270
	12:00	99.0	78	58	8	240
10/2/72	12:33	101.5	68	60	16	220
	13:33	102.0	68	59	15	220
	14:39	101.0	68	59	10	220
	15:04	99.5	68	59	10	220
10/4/72	8:06	108.5	62	55	4	140
	8:53	106.0	65	63	4	100
	10:18	103.5	70	59	4	270
	11:30	99.5	71	56	7	230

*See footnote, page 17

DATA SET NO. 6 (CON'T,

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)
10/5/72	10:05	104.5	71	39	6	270
10/9/72	10:02	107.5	66	69	5	250
10/10/72	11:03	102.5	67	51	5	190
	11:49	104.0	67	58	6	210
	12:34	102.5	68	54	6	220
	14:44	104.0	70	50	9	250
	15:05	106.5	70	50	10	250
10/11/72	8:04	108.0	54	66	3	20
	8:37	100.0	58	64	3	300
	8:54	104.5	60	63	3	250
	12:34	103.5	75	40	7	180
	13:32	103.0	75	42	11	200
	14:38	105.5	74	46	15	250
10/13/72	8:05	102.5	51	66	0	160*
	8:34	105.5	58	67	0	260*
	8:42	103.5	59	67	0	30*
	10:04	104.5	67	56	0	50*
	10:48	102.5	67	50	0	220*
	11:09	100.5	68	48	0	360*
	11:50	104.5	73	48	0	290*
	12:35	101.0	74	49	5	260
	15:07	107.5	75	33	13	240
10/14/72	8:54	106.5	52	50	5	120
	9:04	106.5	53	49	5	130

*See footnote, page 17

DATA SET NO. 6 (CON'T)

Date	Time	SENEL M-1 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)
10/14/72 (Con't)	12:05	103.5	72	55	7	270
	12:08	104.0	72	55	7	270
	12:48	101.5	72	55	9	260

Humidity data obtained from United States Marine Corps Helicopter Air Station, Santa Ana, California, weather reports. Temperature, Wind Speed, and Wind Direction data obtained from Orange County Airport weather reports.

DATA SET NO. 7

Date	Time	SENEL M-2 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)	Visibility (Miles)
10/10/71	7:30	95.5	55	92	4	125	0.3
	11:05	87.0	90	37	0	40*	2.0
	11:28	87.0	92	35	5	210	2.0
	12:35	87.0	94	31	11	240	2.5
	13:04	88.0	94	30	13	270	3.0
	13:58	87.5	89	37	13	260	3.0
10/12/71	7:50	94.0	64	85	0	220*	0.1
	7:52	91.5	64	85	0	100*	0.1
	8:40	89.5	70	78	0	150*	2.0
	8:56	92.5	71	77	0	10*	3.0
	9:55	92.0	76	67	5	250	4.0
	10:33	90.0	75	69	8	235	4.0
	10:50	88.0	74	70	10	225	4.0
	11:00	88.0	74	71	11	220	4.0
	12:37	93.0	73	69	9	240	5.0
	13:03	95.5	73	69	13	240	5.0
	13:39	87.5	73	70	12	240	6.5
11/30/71	10:01	92.0	62	70	7	180	10.0
	10:39	90.5	62	71	9	220	10.0
	10:59	90.5	62	71	10	240	10.0
	11:50	88.0	62	71	10	240	14.0
	12.40	91.0	62	72	11	225	15.0
	13:04	90.5	62	72	12	220	15.0
12/3/71	7:18	82.0	47	86	0	360*	40.0
	7:40	84.0	48	75	0	40*	40.0

*See footnote, page 17

DATA SET NO. 7 (CON'T)

Date	Time	SENEL M-2 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)	Visibility (Miles)
12/3/71	8:02	91.0	49	66	0	190*	40.0
(Con't)	8:34	92.0	52	63	0	230*	40.0
	10:04	91.0	55	53	0	110*	20.0
	10:11	90.0	55	53	0	250*	20.0
	10:35	89.5	56	53	0	320*	20.0
	11:49	91.5	55	57	0	60*	20.0
	11:57	90.5	55	58	0	350*	20.0
	12:35	91.5	54	60	4	240	20.0
12/26/71	9:05	89.0	54	73	5	160	20.0
	10:03	93.0	55	72	10	240	20.0
	10:53	91.0	55	72	12	240	20.0
	11:05	93.0	55	72	12	240	20.0
	12:16	92.0	55	70	15	240	20.0
	12:18	91.5	55	69	15	240	20.0
	13:03	91.0	55	65	15	240	20.0
	13:35	89.0	55	64	14	240	20.0
	13:50	92.0	55	63	13	240	20.0
	13:53	91.5	55	63	13	240	20.0
12/29/72	9:20	92.0	45	91	3	90	40.0
	9:39	92.0	48	88	3	100	40.0
	9:54	96.0	49	86	3	105	40.0
	10:15	90.0	51	82	3	140	40.0
	11:58	91.0	54	68	4	250	20.0
	14:43	89.5	54	68	12	230	16.0

*See footnote, page 17

Temperature and Humidity data obtained from Orange County Agricultural Department weather reports. Wind Speed, Wind Direction, and Visibility data obtained from Orange County Airport weather reports.

DATA SET NO. 8

Date	Time	SENEL M-3 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)	Visibility (Miles)
10/10/71	7:30	91.5	55	92	4	125	0.3
	11:05	86.5	90	37	0	40*	2.0
	11:28	84.5	92	35	5	210	2.0
	12:35	88.5	94	31	11	240	2.5
	13:04	86.0	94	30	13	270	[illegible]
	13:58	86.0	89	37	13	260	3.0
10/12/71	7:50	93.0	64	85	0	220*	0.1
	7:52	95.0	64	85	0	100*	0.1
	8:40	90.5	70	78	0	150*	2.0
	8:56	94.5	71	77	0	10*	3.0
	9.55	92.5	76	67	5	250	4.0
	10:33	91.5	75	69	8	235	4.0
	10:50	89.0	74	70	10	225	4.0
	11:00	87.0	74	71	11	220	4.0
	12:37	88.5	73	69	9	240	5.0
	13:03	92.5	73	69	13	240	5.0
	13:39	88.0	73	70	12	240	6.5
11/30/71	10:01	89.5	62	70	7	180	10.0
	10:39	88.0	62	71	9	220	10.0
	10:59	88.5	62	71	10	240	10.0
	11:50	91.0	62	71	10	240	14.0
	12:40	89.5	62	72	11	225	15.0
	13:04	88.5	62	72	12	220	15.0
12/3/71	7:18	84.5	47	86	0	360*	40.0
	8:02	92.0	49	66	0	190*	40.0
	8:34	97.0	52	63	0	230*	40.0

*See footnote, page 17

DATA SET NO. 8 (CON'T)

Date	Time	SENEL M-3 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)	Visibility (Miles)
12/26/71	9:05	92.0	54	73	5	160	20.0
	10:03	92.0	55	72	10	240	20.0
	10:53	90.5	55	72	12	240	20.0
	11:05	92.5	55	72	12	240	20.0
	12:16	92.0	55	70	15	240	20.0
	12:18	93.0	55	69	15	240	20.0
	13:03	93.0	55	65	15	240	20.0
	13:35	93.5	55	64	14	240	20.0
	13:50	91.5	55	63	13	240	20.0
	13:53	89.5	55	63	13	240	20.0
12/29/72	9:20	92.5	45	91	3	90	40.0
	9:39	90.5	48	88	3	100	40.0
	9:54	95.0	49	86	3	105	40.0
	10:15	90.5	51	82	3	140	40.0
	11:58	91.5	54	68	4	250	20.0
	14:43	91.5	54	68	12	2[illegible]0	16.0

*See footnote, page 17

Temperature and Humidity data obtained from Orange County Agricultural Department weather reports. Wind Speed, Wind Direction, and Visibility data obtained from Orange County Airport weather reports.

DATA SET NO. 9

Date	Time	SENEL M-4 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)
10/6/72	10:07	103.5	86	30	10	40
	10:34	99.5	86	29	10	40
	11:46	99.0	88	30	14	40
	11:47	96.0	88	30	14	40
	12:36	100.5	88	27	15	50
	12:40	95.5	88	27	15	50
	13:25	101.5	90	27	14	50
	13:30	95.0	90	28	13	50
	13:40	100.5	91	28	11	50
	14:12	101.0	92	30	12	80
10/10/72	7:05	103.5	54	87	2	120
	7:15	106.0	55	84	2	110
10/11/72	7:06	102.5	49	73	4	90
	7:19	103.0	50	72	4	80
10/13/72	7:33	100.5	52	74	0	180*
10/14/72	7:03	98.5	51	69	4	90
	7:13	103.0	51	67	4	100
	7:41	101.5	52	62	5	110
10/16/72	7:05	106.0	50	81	4	90
	7:19	104.5	52	79	4	70
10/17/72	7:05	104.5	54	72	5	90
	7:16	104.5	55	72	5	80
10/19/72	7:06	103.5	53	91	5	70
	7:18	106.0	54	90	5	80

*See footnote, page 17

DATA SET NO. 9 (CON'T)

Date	Time	SENEL M-4 (dB)	Temperature (°F)	Humidity (%)	Wind Speed (Knots)	Wind Direction (°From True North)
10/21/72	7:14	105.5	49	94	0	130*
10/26/72	7:06	100.5	49	81	10	70
	7:15	103.5	53	82	10	70
10/27/72	7:15	91.0	54	83	6	90
	8:05	103.5	56	77	7	90
	9:08	104.5	56	76	5	70
	9:10	98.5	56	76	5	70
10/28/72	7:14	101.0	50	85	0	300*
	7:16	102.5]	50	85	0	150*
10/30/72	8:33	107.0	58	36	15	30
	8:52	100.5	59	35	16	30
	9:06	101.0	59	34	15	30
	10:02	101.0	61	29	25	30
	10:52	94.0	62	33	19	30
	11:43	97.5	63	40	14	30
	11:48	105.5	64	41	13	30
	12:36	93.5	66	33	12	30
	13:34	101.5	67	26	12	30
	15:04	102.5	67	26	15	30
10/31/72	7:01	94.5	68	35	8	140
	7:14	99.0	69	35	7	140

*See footnote, page 17

Humidity data obtained form United States Marine Corps Helicopter Air Station, Santa Ana, California, weather reports. Temperature, Wind Speed, and Wind Direction data obtained from Orange County Airport weather reports.

APPENDIX B
RESULTS OF ANALYSIS RUNS

SET 1. (N=49 data sets)

ANALYSIS OF VARIANCE

Source	d.f.*	ss*	ms*	F*	Sig.*
X_1	1	0.642	0.642	0.07	-
X_2	1	48.746	48.746	4.98	+
X_3	1	0.045	0.045	0.005	-
X_4	1	137.247	137.247	14.02	+++
X_5	1	1.670	1.670	0.17	-
Residual Error	43	420.998	9.791		
Totals	48	609.347			

OVERALL CORRELATION ESTIMATE

$$R = 0.556$$
$$R^2 = 0.309$$

PREDICTION EQUATION

$$\hat{Y} = 228.64 - 0.016X_2 - 43.77X_4$$
$$s_E = 3.13$$

where

		Range of Data Set	
		Low	High
Y	= Noise level in CNELdB, Mike #1	94.5	112.0
X_1	= Wind speed (knots)	0	15
X_2	= Wind direction, deg. from True North	0	360
X_3	= Visibility (miles)	0.1	40.0
X_4	= $e^{T/528}$, where T=temperature in °R	505	554
X_5	= Relative humidity in %	30	92

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*d.f. = degrees of freedom; ss = sums of squares; ms = mean square; F = F-test ratio; sig. = significance code.

SET 2. (N=35 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_2	1	30.404	30.404	4.16	+
X_4	1	98.940	98.940	13.54	+++
Residual Error	32	233.841	7.308		
Totals	34	363.185			

OVERALL CORRELATION ESTIMATE

$$R = 0.597$$
$$R^2 = 0.356$$

PREDICTION EQUATION

$$\hat{Y} = 178.16 - 0.0020X_2 - 27.34X_4$$

$$s_E = 2.70$$

where

		Range of Data Set Low	High
Y	= Noise level in CNELdB, Mike #1	97.0	112.0
X_2	= Wind direction, deg. from True North	0	360
X_4	= $e^{T/528}$, where T=temperature in °R	505	554

SET 3. (N=35 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_2	1	19.053	19.053	2.38	-
X_4	1	88.289	88.289	11.04	++
Residual Error	32	255.843	7.995		
Totals	34	363.185			

OVERALL CORRELATION ESTIMATE

$$R = 0.544$$
$$R^2 = 0.296$$

PREDICTION EQUATION

$$\hat{Y} = 111.19 - 0.1021X_4$$
$$s_E = 2.83$$

where

		Range of Data Set Low	High
Y	= Noise level in CNELdB, Mike #1	97.0	112.0
X_2	= Wind direction, deg. from flight path	0	360
X_4	= Temperature in °R	505	554

SET 4. (N=43 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_1	1	0.168	0.168	0.02	-
X_2	1	5.369	5.369	0.50	-
X_3	1	17.825	17.825	1.67	-
Residual Error	39	415.766	10.661		
Totals	42	439.128			

OVERALL CORRELATION ESTIMATE

$R = 0.231$
$R^2 = 0.053$

PREDICTION EQUATION

$\hat{Y} = 104.09$ (equals $\bar{Y}$ since no variables are significant)

$s_E = 3.27$

where

		Range of Data Set Low	High
Y	= Noise level in CNELdB, Mike #1	94.5	108.5
X_1	= $e^{T/528}$, where T=temperature in °R	505	536
X_2	= Flight path downwind vector - wind sp. / wind dir.	0 0	15 360
X_3	= Reciprocal of ceiling, $(\text{feet})^{-1}$	900	0

SET 5. (N=49 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_1	1	52.80	52.80	4.32	+
X_2	1	2.86	2.85	0.23	-
X_3	1	3.53	3.53	0.29	-
Residual Error	45	550.16	12.226		
Totals	48	609.35			

OVERALL CORRELATION ESTIMATE

$$R = 0.312$$
$$R^2 = 0.097$$

PREDICTION EQUATION

$$\hat{Y} = 144.12 - 15.111X_1$$
$$s_E = 3.50$$

where

		Range of Data Set: Low	Range of Data Set: High
Y	= Noise level in CNELdB, Mike #1	94.5	112.0
X_1	= $e^{T/528}$, where T=temperature in °R	505	554
X_2	= Flight path downwind vector, in knots wind sp.	0	15
X_3	= Flight path crosswind vector, in knots wind dir.	0	360

SET 6. (N=74 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_1	1	57.274	57.274	5.84	+
X_2	1	5.112	5.112	0.52	-
X_3	1	15.668	15.668	1.60	-
X_4	1	24.236	24.236	2.47	-
Residual Error	69	677.251	9.815		
Totals	73	779.541			

OVERALL CORRELATION ESTIMATE

$$R = 0.362$$

$$R^2 = 0.131$$

PREDICTION EQUATION

$$\hat{Y} = 142.75 - 12.518X_1$$

$$s_E = 3.13$$

where

		Range of Data Set: Low	High
Y	= Noise level in CNELdB, Mike #1	92.5	108.5
X_1	$= e^{T/528}$, where T=temperature in °R	511	548
X_2	= Relative humidity in %	33	86
X_3	= Wind direction, deg. from True North	0	360
X_4	= Wind speed, knots	0	16

SET 7. (N=49 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_1	1	0.528	0.528	.09	-
X_2	1	14.153	14.153	2.39	-
X_3	1	0.149	0.149	.03	-
X_4	1	65.118	65.118	10.98	++
X_5	1	4.862	4.862	.82	-
Residual Error	43	255.242	5.936		
Totals	48	339.918			

OVERALL CORRELATION ESTIMATE

$$R = 0.499$$
$$R^2 = 0.249$$

PREDICTION EQUATION

$$\hat{Y} = 148.43 - 21.613X_4$$
$$s_E = 2.44$$

where

	Range of Data Set: Low	Range of Data Set: High
Y = Noise level in CNELdB, Mike #2	82.0	96.0
X_1 = Wind speed, knots	0	15
X_2 = Wind direction, deg. from True North	0	360
X_3 = Visibility, miles	0.1	40.0
$X_4 = e^{T/528}$, where T=temperature in °R	505	554
$X_5 = e^{H}$, where H=humidity in %	30	92

SET 8. (N=43 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_1	1	4.584	4.584	0.64	-
X_2	1	9.322	9.322	1.30	-
X_3	1	13.091	13.091	1.83	-
X_4	1	58.831	58.831	8.23	++
X_5	1	1.063	1.063	0.15	-
Residual Error	37	264.586	7.151		
Totals	42	351.477			

OVERALL CORRELATION ESTIMATE

$$R = 0.497$$
$$R^2 = 0.247$$

PREDICTION EQUATION

$$\hat{Y} = 150.03 - 21.907X_4$$
$$s_E = 2.67$$

where

		Range of Data Set Low	High
Y	= Noise level in CNELdB, Mike #3	84.5	97.0
X_1	= Wind speed, knots	0	15
X_2	= Wind direction, deg. from True North	0	360
X_3	= Visibility, miles	0.1	40.0
X_4	= $e^{T/528}$, where T=temperature in °R	505	554
X_5	= e^H, where H=relative humidity in %	30	92

SET 9. (N=45 data sets)

ANALYSIS OF VARIANCE

Source	d.f.	ss	ms	F	Sig.
X_1	1	7.012	7.012	0.58	-
X_2	1	95.408	95.408	7.92	++
X_3	1	29.073	29.073	2.41	-
X_4	1	8.526	8.526	0.71	-
Residual Error	40	482.092	12.052		
Totals	44	622.111			

OVERALL CORRELATION ESTIMATE

$$R = 0.474$$
$$R^2 = 0.225$$

PREDICTION EQUATION

$$\hat{Y} = 118.52 - 6.801X_2$$
$$s_E = 3.47$$

where

		Range of Data Set	
		Low	High
Y	= Noise level in CNELdB, Mike #4	91.0	106.0
X_1	= Wind direction, deg. from True North	0	360
X_2	= Wind speed, knots	0	25
X_3	= $e^{T/528}$, where T=temperature in °R	509	552
X_4	= e^H, where H=relative humidity in %	26	94