40. COMMUNITY REACTIONS TO AIRCRAFT NOISE

NOISE MEASUREMENTS

By William K. Connor

TRACOR, Inc.

SUMMARY

Aircraft noise measurements were made in communities exposed in varying degrees to the noise of flight operations from major airports. The primary purpose of these measurements was to define the noise exposure for a 3-month period in areas for which social data were also obtained by means of interviews. The acoustical and social data are being used in a study of community reaction to aircraft noise. Further data must be taken before an extensive analysis is performed. A secondary purpose of the noise measurement program was to evaluate, in a community context, noise level estimates obtained from the guide "Land Use Planning With Respect to Aircraft Noise." A comparison of measured noise levels with the estimates revealed no inconsistencies in 85 percent of the cases examined, and the discrepancy was in no case greater than 10 PNdB. The noise data also afforded a comparison of several acoustical parameters which are used as measures of aircraft noise. For such community data, there was a standard deviation of 3 units or less between any two parameters, except for certain pairs including speech interference level.

INTRODUCTION

This paper and reference 1 describe a current program of research concerning community reaction to aircraft noise (under Contract NASw-1549). Although procedures for computing psychophysical parameters of aircraft noise are well developed (ref. 2), there as yet exists no methodology capable of accurately predicting the reaction of individuals or groups to a given noise exposure. Annoyance resulting from aircraft noise has been known to vary from one person or community to another under identical exposure conditions. The social and psychological factors which may account for such variations are the central focus of this study.

The paper at hand deals with the aircraft noise exposure data related to this study. The social data and analysis are discussed in the coordinate paper by Hazard (ref. 1).

DISCUSSION

Survey Program

The plan of research requires that both social and acoustical data be taken around several major commercial airports located in cities of the United States. The areas in which such data were acquired were confined to within a 12-mile radius of the airport in question. A further delineation of survey areas was made by using a sampling plan which selected a balanced cross section of the population from the standpoint of socioeconomic and noise exposure variables.

The actual sample ultimately consisted of from 11 to 22 census tracts in each city. Many of these census tracts were situated more or less on a line extended from the ends of principal runways. The noise exposure in such tracts tended to be due-largely to aircraft flyovers associated with the particular runway. In other sample areas located within 3 miles of the airport, noise exposure was due to a combination of flyovers, other flight operations, and ground operations. The sample tracts were surveyed by both social and acoustical scientists, but not necessarily at the same time.

The program is comprised of two active phases of approximately 1 year each. In the first phase, four cities were surveyed in the summer of 1967. In the second phase, not yet begun, data will be obtained in three more cities. Only a preliminary analysis has been made of the data now available. A comprehensive analysis culminating in major conclusions can be performed only after the survey data from all seven cities are available.

Exposure to Aircraft Noise

Requirements for acoustical data.- The primary function of the acoustical measurements is to define the aircraft noise exposure for each of the sample areas for a period of at least 3 months immediately prior to the social survey. This minimum period was agreed upon in consultation with other scientists active in the general field of human reaction to noise. It was also agreed that the best formulation of long-term aircraft noise exposure was in terms of PNdB with corrections for discrete frequency components, This formulation requires that the acoustical data be analyzed by using bands no wider than 1/3 octave and that the noise be sampled at least once per second in real time. A secondary purpose of the field measurements is to obtain some validation of the aircraft noise level contours in the guide "Land Use Planning With Respect to Aircraft Noise" (ref. 3), hereinafter referred to as "Land Use Planning." The fundamental question to be answered is, "How do noise levels predicted on the basis of the guide compare with levels measured in various communities?" Obviously, the usefulness of the guide is contingent upon the answer to this question.

Data acquisition.- The acoustical data requirements entailed tape recording of aircraft noise at the various survey sample areas in each city. The recording systems incorporated automatic electrical calibration after each noise recording and a 48-interval time-of-day encoded signal. Both calibration and time signals were recorded on the data tapes. The recording site, apparent aircraft operations (when visible), and general observations were logged and keyed to the data tape reels. An additional feature of the recording systems was an automatic monitor and control unit whereby recording was initiated when the A-weighted sound pressure level (SPL) exceeded a preset value. A member of the measurement team was in attendance at all times, however.

Data processing.- The large amount of recorded acoustical data necessitated automatic analysis. An analog/digital system built for this purpose is shown in block-diagram form in figure 1. The system output, in digital tape form, consists of SPL's in each of twenty-four 1/3-octave bands (as well as A-weighted (ref. 4) and N-weighted (ref: 5) SPL's) for each second of analog data tape, together with appropriate identification and index markers. These data were further processed with a series of routines on the UNIVAC 1108 computer to produce a second set of digital tapes which contained the values of a number of psychophysical parameters (perceived noise levels in PNdB (refs. 6 and 7), with and without corrections for discrete frequency components; loudness level in phons (ref. 8); speech interference levels; etc.), again for 1-second sampling intervals. These tapes also included values of peak levels, durations of various parameters above given thresholds, and other pertinent information.

Determination of noise exposure.- It was impossible for several reasons to sample aircraft noise continuously in each survey tract over the entire 3-month period of interest. Therefore, the procedure shown in block form in figure 2 was used in the process of computing long-term noise exposure. Noise data were taken in as many tracts as possible under known airport operating conditions. These conditions included the type of operation of heavy aircraft (landing or take-off) as well as the runway usage during each noise-recording period.

Hourly wind data for the 3 months of interest, together with information from the airport control-tower staff concerning local runway-assignment practices as related to wind conditions, were processed with a simple computer routine to determine runway usage over the 3-month period. This usage factor was multiplied by the airport operations count (a function of time of day) to obtain the number and type of heavy-aircraft operations utilizing each runway according to time of day, averaged over the 3-month period. An additional weighting factor related to flight path made it possible to obtain the average number of operations passing over or near each sample tract.

The average number of operations and the maximum PNL occurring during each particular type of operation were combined into the following noise exposure index for use in the preliminary analysis of the combined social and acoustical data:

$$\text{Exposure index} = \text{PNL} + A \log_{10}\left(N_{day} + BN_{night}\right)$$

where

PNL maximum measured flyover perceived noise level, energy-averaged for all observed flyovers of a particular type

N_{day}, N_{night} number of daytime, nighttime flyovers of the particular type

A,B constants

This index is a general case of the composite noise rating (CNR) formulation (ref. 3), which has had considerable use. A value (or set of values) was assigned to each sample tract which was surveyed in the field study. (In actuality, one further step was involved in determining the noise exposure values: The indices for all aircraft operation types affecting each tract were combined on an energy-addition basis.)

For some tracts, noise data could not be obtained in the field for all operating conditions. However, it was usually possible in these cases to use data taken at a site symmetrically opposite the airport. These data were applicable to the subject tract when the direction of aircraft operations was reversed. If no field noise data whatsoever could be obtained, noise contours for the most prevalent aircraft types taken from "Land Use Planning" were used to estimate maximum flyover levels.

Results of Preliminary Analysis

Aircraft operations data.- A plot of the aircraft operations count as a function of time of day for each of the four airports studied thus far is shown in figure 3. Although the airports varied considerably in size, the daily pattern of operations was remarkably uniform from one to another. This pattern may be partially attributed to public travel requirements. It is also noteworthy that nighttime operations, which are known to produce considerable annoyance and complaints, represent only a small fraction of the total number.

Noise level data.- The aircraft noise recorded at the various survey sites, after the processing described previously, was analyzed to find the maximum PNL value for each flyover. The results were plotted for each of 73 original data tape reels in the form of a distribution. Two such distributions are shown in figures 4 and 5. Each distribution applies to a single survey site and usually to a particular known mode of operation of the airport. Corrections for discrete frequency noise components were not included in these PNL values, in order to make possible a direct comparison with the uncorrected PNL's of the "Land Use Planning" contours. The energy averages of these distributions were used in computing the noise exposure indices for the various survey tracts according to the formula given in a foregoing section.

An interesting aspect of the PNL distributions is the variation in their shape from one survey tract to another. In some (fig. 4), there is a highly peaked distribution, which indicates a predominance of aircraft noise from a single type of operation (and aircraft). In others (fig. 5), there is a quite broad distribution, which perhaps indicates contributions from aircraft operations on more than one runway as well as variations in aircraft, flight procedure, trajectory, and so forth. The procedure of energy averaging, although consistent with accepted practice, places the greatest emphasis upon the highest observed PNL values in these distributions. In consequence, essentially no effect is attributed to flyover noise much below the highest level. It would seem that a number of flyovers with maximums of 90 PNdB are significant in terms of human annoyance even if an equal number attained 100 PNdB. Therefore, further analysis of the data will include formulations for correlation with annoyance measures derived from the social data which give greater weight to the less noisy flyovers above a certain threshold level.

For each of the PNL distributions, estimates of the noise maximums were made by using the "Land Use Planning" contours for civil aircraft ranging from four-engine piston and turboprop aircraft to four-engine jet aircraft. These estimates were based upon the operations proximal to the recording site under the prevailing wind conditions. The range of these estimates is shown above the plots of figures 4 and 5 for comparison. A positive indication of inconsistency between the predicted and the measured levels is for the latter to exceed the former significantly. (The reverse situation may mean only that the noisier aircraft or operations are not represented.) Such an indication was present in 11 of the 73 distributions. The maximum difference between the highest predicted and the highest measured levels was 10 PNdB. It may be concluded that the "Land Use Planning" contours afford a reasonably good estimate of aircraft noise levels provided that vagaries of local operation are known and taken into account.

Comparison of noise parameters. - The format of the analyzed, computer-processed acoustical data made possible a ready comparison of several noise parameters associated with effects on humans. Similar comparisons have been made (refs. 9, 10, and 11), but not for so large a mass of data (about 4730 flyovers) or for acoustical data so well-distributed over a wide range of community exposure conditions. Some of the parameters to be compared herein are defined for the present purpose as follows:

PNdB1 maximum flyover PNdB value computed (with pure tone corrections) from 1/3-octave band data sampled once per second

PNdB2 PNdB1 without pure tone corrections

PNdB3 PNdB value computed (without pure tone corrections) from maximum flyover levels occurring in each 1/3-octave band (not necessarily simultaneously), sampled once per second (ref. 12)

PHONS maximum flyover value of loudness level computed according to Stevens' Mark VI method (ref. 8)

dBN maximum flyover SPL weighted according to inverse of 40-noy contour (ref. 5); zero reference at 1 kHz

dBA maximum flyover A-weighted SPL (ref. 4)

SIL maximum flyover speech interference level (arithmetic average of SPL's in the 1-kHz, 2-kHz, and 4-kHz octave bands)

The numerical differences between the values of every pair of these parameters were analyzed for approximately 4730 recorded flyovers. The results are shown in matrix form in the following table:

	PNdB2	PNdB3	PHONS	dBN	dBA	SIL
PNdB1	2.6/1.4*	1.2/1.5	4.1/2.6	9.7/2.6	14.2/3.0	25.0/2.8
PNdB2	-------	-1.4/1.0	1.5/1.7	7.1/1.8	11.6/2.2	22.4/2.9
PNdB3	-------	--------	2.9/1.8	8.4/1.9	13.0/2.4	23.8/3.1
PHONS	-------	--------	------	5.5/1.8	10.1/2.0	20.8/3.8
dBN	-------	--------	------	------	4.6/2.1	15.3/3.9
dBA	-------	--------	------	------	-------	10.8/3.8

*Average for all flyovers of (value in left-hand column minus value of row parameter)/standard deviation.

The usefulness of each noise measure as applied to community-wide aircraft noise is apparent from the data of the table. It can be seen that the three PNdB-type measures correlate with one another quite well; the spread is no larger than that normally encountered in the data of psychophysical comparisons of such noise. The various measures in the table are in order of descending correlation with PNdB1, the most recent and sophisticated form. The two weighted-SPL measures, with standard deviations with respect to PNdBl of 2.6 and 3.0 units, should certainly be adequate for most aircraft noise measurements. PNdBl should be used for limited classes of data and for aircraft-certification purposes, however. The SIL's can hardly be expected to correlate well with perceived noise levels, but it is also of interest to see if they can be approximated by dBA or dBN. Unfortunately, a reasonable approximation cannot be made, although this does not necessarily mean that dBA is not a useful speech interference measure itself. Indeed it has been shown that, for some types of noise at least, dBA is fully as good a measure as the SIL as computed for the present comparison. (See ref. 13.)

CONCLUDING REMARKS

In the first phase of this study, now complete, a large mass of acoustical data was acquired. These data were used to derive a noise exposure index for the preliminary analysis of the social data and also for secondary evaluations. Following the anticipated second phase of the study, the complete acoustical data will be further analyzed to test the relative power of several different formulations of noise exposure in predicting community reaction.

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BLOCK DIAGRAM OF ACOUSTICAL DATA-PROCESSING SYSTEM

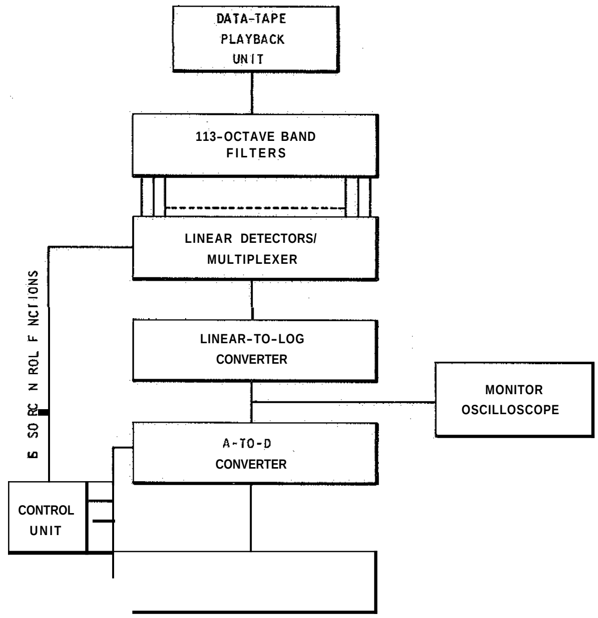

Figure 1

PROCEDURE FOR COMPUTING HOURLY NOISE EXPOSURE IN A GIVEN SURVEY TRACT

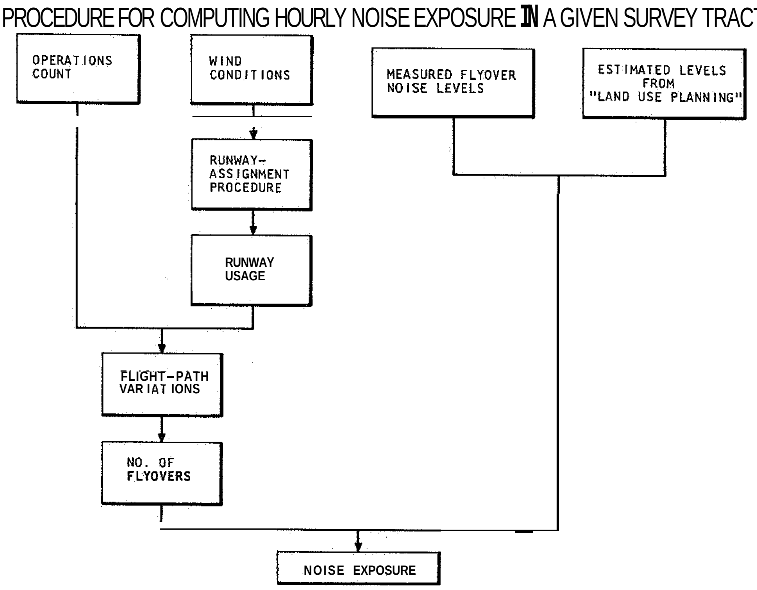

Figure 2

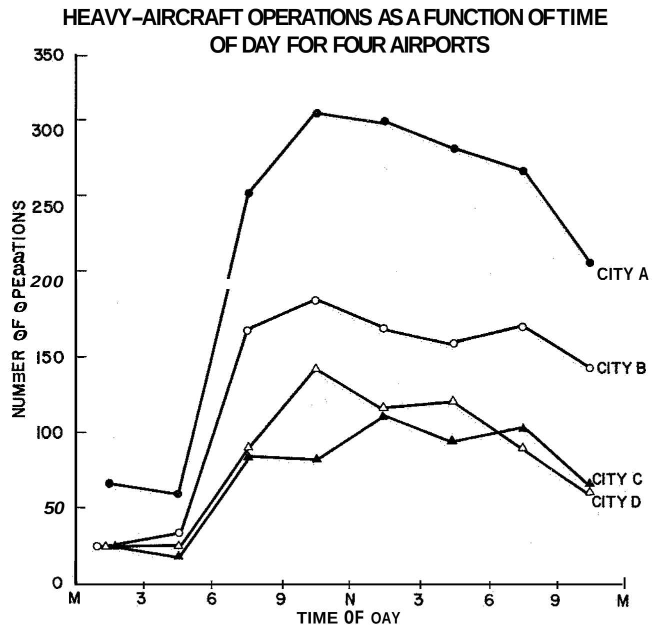

Figure 3

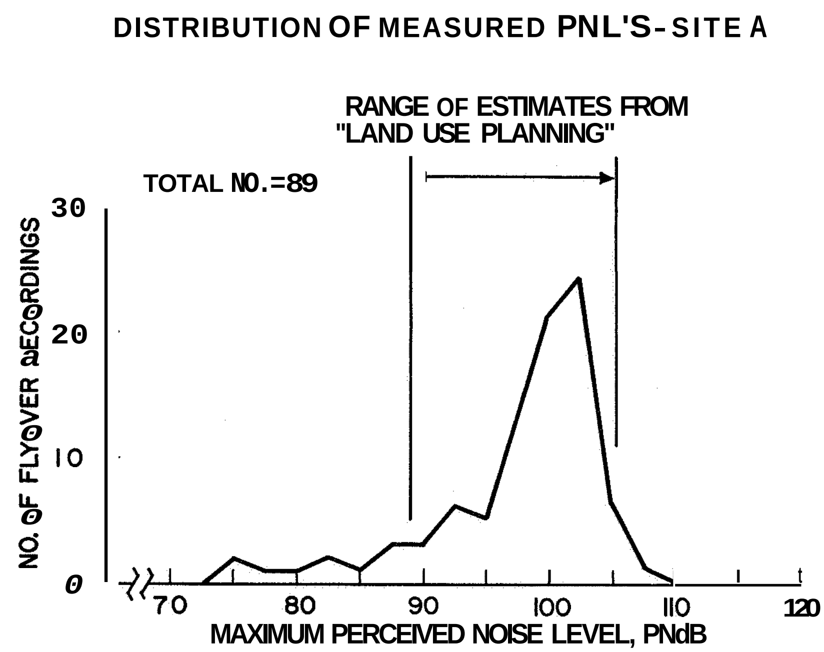

Figure 4

DISTRIBUTION OF MEASURED PNL'S - SITE B

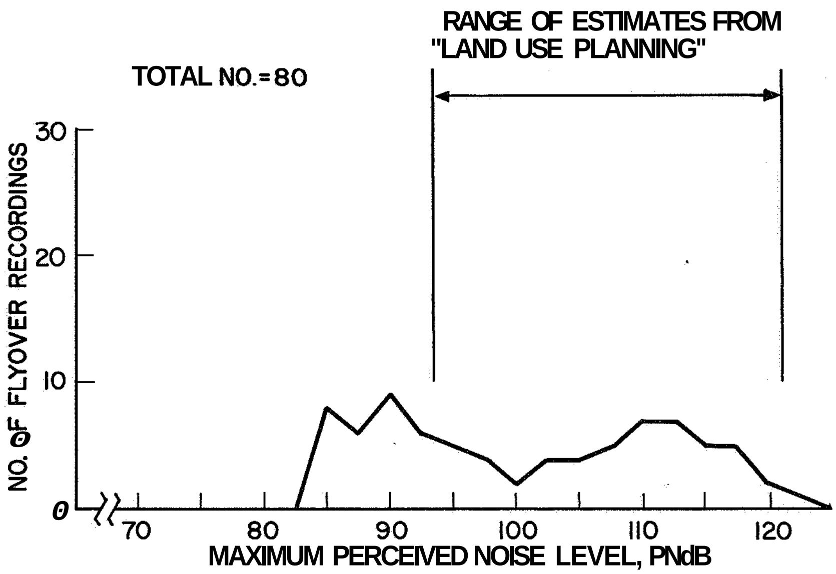

Figure 5