24. VARIABILITY IN AIRPLANE NOISE MEASUREMENTS

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SUMMARY

This paper presents some of the acoustic data obtained during two measurement projects involving a 727 turbofan airplane and an 880 turbojet airplane *along* with information relating to airplane position and meteorological conditions during the tests. Data apply to ground-to-ground and air-to-ground measurement situations for distances of about 1500 feet.

The studies indicate that, even under controlled conditions, variations can occur in acoustic measurements. Such variations are due to several factors, some of which can be compensated for. Weather and terrain are significant factors in measurement variability, particularly at long distances and for the higher frequencies.

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INTRODUCTION

In making measurements to evaluate the noise characteristics of an airplane, there are several factors that can cause variations in such measurements. These factors are the airplane operating conditions, weather, terrain, and instrumentation and procedures. In order to demonstrate the manner in which such factors can affect measured acoustic data, the results from practice noise evaluation exercises are presented. These data were obtained in cooperative projects of the National Aeronautics and Space Administration with the Federal Aviation Administration. At the National Aviation Facilities Experimental Center (NAFEC) a 727 airplane was used in landing and take-off noise studies; at the NASA Wallops Station an 880 airplane was used in flyover studies. The purpose of this paper is to present the pertinent results of these studies and to indicate the nature of the variations observed in the measured quantities.

NAFEC PROJECT

Test Arrangement

Figure 1 contains the general layout for the NAFEC noise measurement project. The purpose of the project was to define the noise footprint of a representative commercial turbofan airplane during take-off and landing. Noise measurements along the sideline during the take-off roll of the airplane, under the airplane during the climbout phase, and under the airplane during the approach phase were required. In order to make these measurements, microphones were located along a line 1500 feet from the runway center line as shown in figure 1 and also under the flight track in the climbout and landing-approach areas.

Noise Data

Figure 2 contains a plot of the overall sound pressure levels (SPL) as measured at the microphone stations along the 1500-foot sideline array. Data are included for 10 controlled flights of the 727 airplane during a 3-hour period. The maximum sound pressure levels are measured to the rear of the airplane while it is still in a near static condition. Then, as the airplane begins to roll and the forward speed increases, the sound pressure levels decrease. After the airplane rotates and clears the ground, a slight increase in overall sound pressure level is observed. As the airplane climbs out and gains altitude, the sound pressure levels begin to decrease slightly as the slant distance increases. The square symbols represent measurements made on the opposite side of the runway from the circle symbols and have been included in the plot to show that comparable measurements were approximately equal on both sides of the runway. The spread in the acoustical data at each station is of the order of 5 dB. The data in figures 3 and 4 show the spectral content as measured at two of the microphone stations.

In figures 3 and 4, $\frac{1}{3}$-octave band measurements are plotted for two different microphone positions. One microphone was located at the 1500-foot sideline distance but to the rear of the airplane, the measurement being made while the airplane was in a near static configuration (fig. 3). The other microphone was under the flight path of the airplane, and the measurements were taken when the airplane passed overhead at an altitude of about 1600 feet (fig. 4). In both figures the hatched area represents the spread of the sound pressure levels in each frequency band for the 10 flights. In the ground-to-ground case (fig. 3) the lower frequency band levels (below 100 Hz) varied about 5 dB, whereas the higher frequency band levels (above 500 Hz) varied as much as 20 dB. In the air-to-ground case (fig. 4) the variations across the full range of the spectra were markedly less and exceeded 5 dB only at frequencies above 2000 Hz. In both cases the overall noise levels varied about 5 dB because they were controlled by the lower frequency portions of the spectra. The data of figures 3 and 4 are believed to be representative of measurements for conditions when the airplane was under close control. The variations observed are judged to result from several sources.

Sources of Measurement Variability

The four main sources of measurement variability are believed to be instrumentation, terrain, operating parameters of the airplane, and changes in meteorological conditions.

Instrumentation and terrain. - Instrumentation and terrain were not varied in the tests. The terrain was uniformly flat, open, and had sparse grassy ground cover in all measurement areas. The instrumentation was of the same type and was operated in the same manner at each station. Changes in the characteristics of the instrumentation and the terrain during the 3-hour test period are believed to be minimal.

Airplane operations. - Figure 5 contains a plot of the airplane lateral displacement and altitude time histories for 10 flights. Take-off power was applied to the engines at the start of the roll and was held constant until the airplane passed the last measuring station. The airplane position over the measuring station varied approximately 400 feet in lateral displacement and approximately 600 feet in altitude during the 10 flights. These variations in flight path are sufficient to affect the noise-level values. Corrections can be made for variations in distance, but no attempt was made to include such corrections in the data of this paper.

Meteorological conditions. - The other significant variable that affects the acoustic data is the local meteorology. Figure 6 shows variations in some meteorological quantities for the time period during which these 10 flights were made. Temperature, absolute humidity, wind velocity, and wind direction are plotted as functions of altitude. The hatched regions represent the variations in the measurements at the various altitudes. These data were obtained by means of modified rawinsondes that gave continuous readings of temperature and relative humidity. The balloons were tracked by dual theodolites to obtain the wind information. Throughout the test period the wind velocity did not exceed 7 knots at the surface, did not exceed 18 knots at any altitude of interest, and the direction remained constant at an azimuth angle of about 200°. During the test period there were no sharp temperature inversions. Temperature and relative humidity values changed somewhat; however, the absolute humidity remained essentially constant during this time. Some atmospheric variables can be accounted for; however, in a situation such as the one described, insufficient data are available to accomplish meaningful corrections.

WALLOPS STATION PROJECT

Longer term variations in acoustic measurements are shown in figure 7 which contains data measured during 57 flights of an 880 turbojet airplane. These flights were made at a constant altitude of 1400 feet and a constant power condition (engine pressure ratio (EPR) equals 2.0) over a 10-day period. These acoustic data were measured during subjective noise studies at the Wallops Station, and the meteorological conditions that existed during these flights were of the same order as those shown in figure 6.

Statistical Analysis

In figure 7 a histogram has been plotted of the acoustic data that were measured directly under the flight track of the airplane. The maximum value of the overall sound pressure level was determined as the airplane passed overhead. The number of events associated with each maximum sound pressure level value are plotted in figure 7. The spread in the measurements amounts to approximately 6 dB. The standard deviation σ for these data is 1.1 dB; that is, 68 percent of the data are within -11.1 dB of the mean value.

SUMMARY OF VARIABILITIES

Data have been presented from two flyover measurement projects, and it has been shown that variations occur in the measured acoustic data. In table I an attempt is made to evaluate the effects of several factors contributing to variations in acoustic measurements. The various factors which are sources of measurement variability are listed, and values are assigned to each of these. Instrumentation stability is within ±0.2 dB over the entire spectrum. Instrument calibration and data reading operations have associated with them a ±0.5-dB error across the spectrum. It is estimated that changes in the outside air temperature may cause noise-level changes of ±1.0 dB even though the engine pressure ratio was held constant. When the airplane was flown under radar control, ±1.5-dB variations were caused by variations in airplane distance from the measurement locations. Standard procedures are available to compensate for distance. If reasonable care is not taken in conducting the operation, instrumentation and airplane effects on the

TABLE I.- SUMMARY OF VARIABILITIES

Variable	ΔdB low frequency	ΔdB high frequency
Instrument stability	rt0.2	±0.2
Instrumentation operations	±.5	±.5
Airplane power	±1.0	±1.0
Airplane position	±1.5	-11.5
Atmosphere (air to ground)	±2.0	±3.0
	±2.0	±10.0
distance, 1500 ft		

data can be greater than those indicated. The data in the last two items of table I contain the effects of the factors just discussed plus those associated with the atmosphere and terrain. For air-to-ground propagation, where mainly the atmosphere is involved, variations of ±3.0 dB were observed; however, for ground-to-ground propagation where the atmosphere and terrain may affect the data, variations of up to ±10.0 dB were observed. For measurement distances of the order of 1500 feet, the atmosphere and terrain are significant factors.

CONCLUDING REMARKS

Under controlled conditions variations can occur in acoustic measurements. These variations are due to several factors, some of which can be compensated for. Atmosphere and terrain are significant factors in measurement variability, particularly at long distances and for the higher frequencies.

TEST ARRANGEMENT

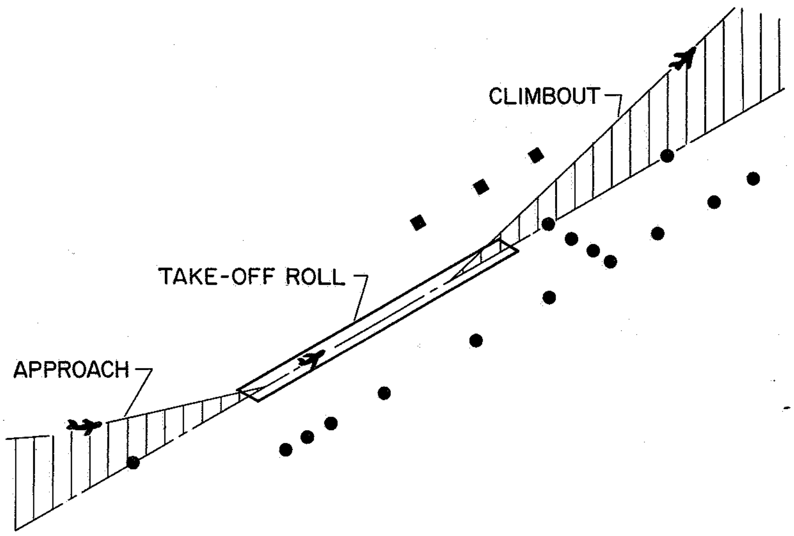

Figure 1

SIDELINE NOISE MEASUREMENTS

DISTANCE = 1500 ft

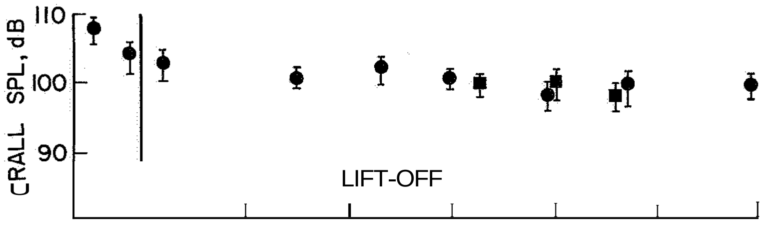

Figure 2

VARIABILITY OF MEASURED SPECTRA
GROUND TO GROUND; DISTANCE = 1500 ft

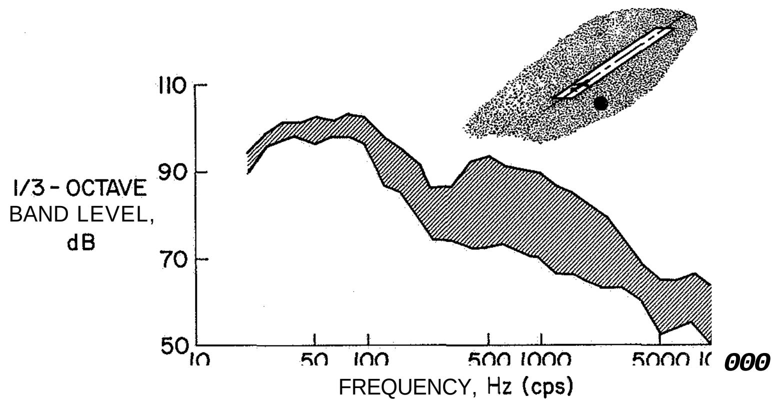

Figure 3

VARIABILITY OF MEASURED SPECTRA
AIR TO GROUND; ALTITUDE = 1600 ft

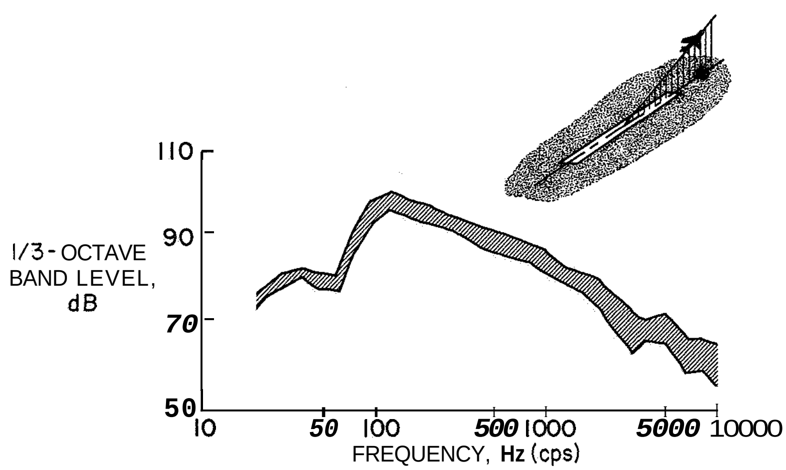

Figure 4

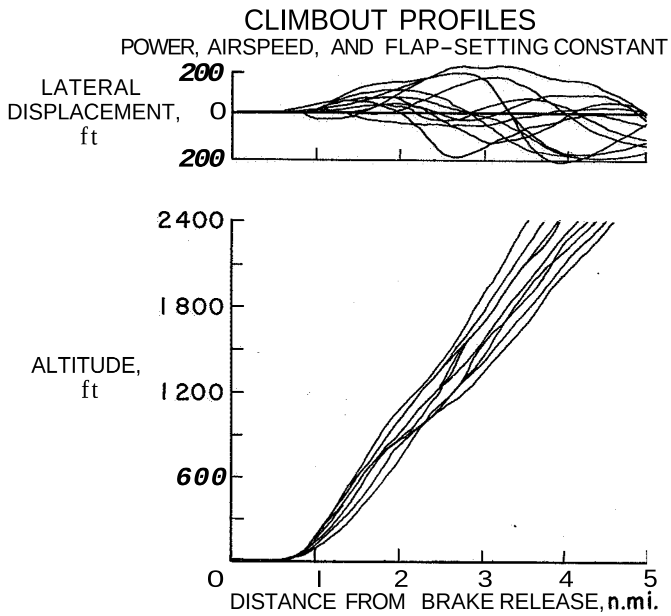

Figure 5

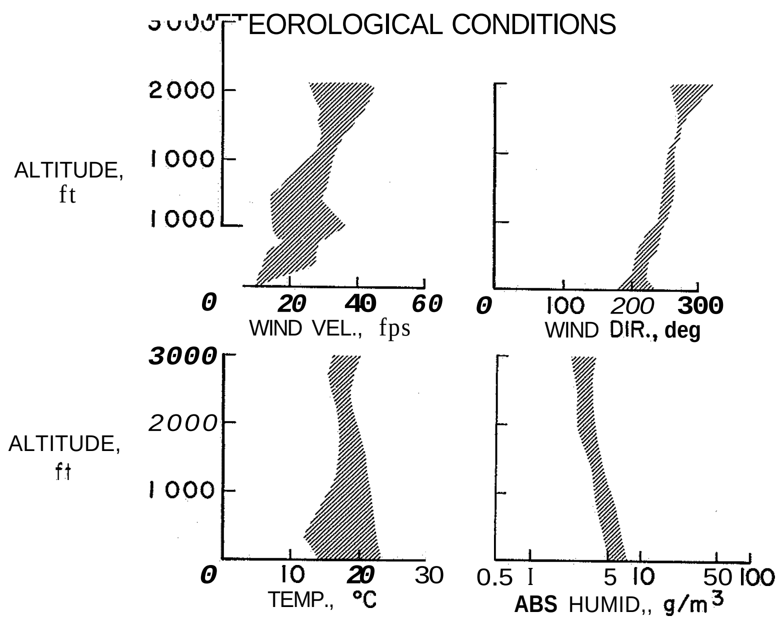

Figure 6

NOISE MEASUREMENT VARIATIONS FOR 57 FLYOVERS

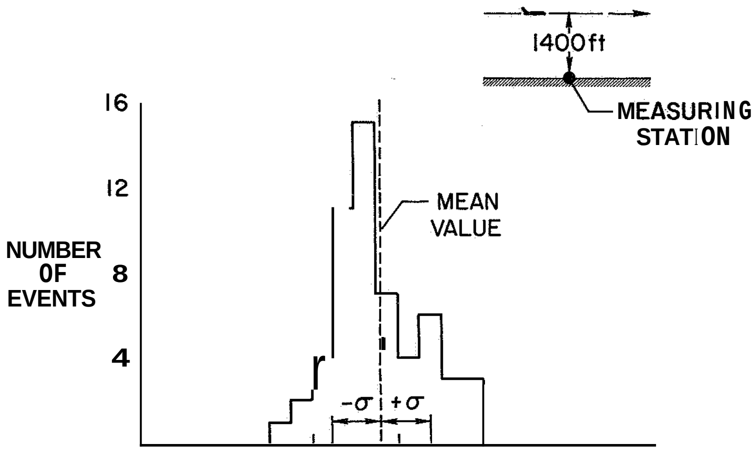

Figure 7